ERNATIONAL WATER SUPPLY ASSOCIATION

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Contents

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Paper 1a

Water-Related Diseases and the Broad Principles of Water Treatment Applicable to the Third World

A synopsis by Dr. E. Windle Taylor, (U.K.)

Introduction.

What has happened in the past hundred years

Medical Bacteriology - the isolation and study of pathogenic (disease-producing) micro-organisms

Epidemiology - the study of outbreaks of infectious disease and the assessment of methods of control

Great reduction in morbidity and mortality in developed countries, but elsewhere there are large areas still affected and huge populations still suffering from the effects of communicable diseases. (1)

Our problem is concerned with those illnesses in which water plays a part.

Biological groups of organisms involved

Viruses

Bacteria

Protozoa

Helminths (worms)

Most important viral, bacterial and protozoan pathogens found in excreta (2)

Man, and in some cases animals, are the reservoirs (sources) of infection and, in addition, symptomless human carriers (excretors) exist.

BIOLOGICAL GROUP	ORGANISM	DISEASE OR SYMPTOMS
Viruses	Polio virus	Poliomyelitis
	Hepatitis A virus	Infectious hepatitis
	ECHO virus Cocksackie virus	Fever, diarrhoea, vomiting, etc.
	Rotavirus	Gastro-enteritis in children
Bacteria	Vibrio cholerae	Cholera
	Salmonella typhi	Typhoid fever
	Salmonella paratyphi	Paratyphoid fever
	Other salmonellae	Gastro-enteritis
	Shigella spp.	Bacillary dysentery
	Leptospira spp.	Fever, jaundice etc.
Protozoa	Entamoeba hystolytica	Amoebic dysentery and liver abscess
	Giardia lamblia	Diarrhoea and malabsorption
	Balantidium coli	Mild diarrhoea

Most important diseases involving worms (helminths)

COMMON NAME	PATHOGEN	TRANSMISSION	DISTRIBUTION
Bilharzia Schistosomiasis	Schistosoma haematobium	Man-aquatic snail -Man	Africa, Middle East, India
	S.mansoni	Man-aquatic snail -Man	Africa, Latin America, Arabia
	S.japonicum	Animals and man-snail-man	S.E. Asia
Beef tapeworm	Taenia saginata	Man-cow-man	World wide
Pork tapeworm	Taenia solium	Man-pig-man	World wide
Round worm	Ascaris lumb-ricoides	Man-soil-man	World wide
Hook worm	Ankylostoma duodenale	Man-soil-main	Latin America, Africa, India, S.E. Asia
Guinea worm	Dracunculus medinensis	Man-daphnia (water flea)-man	Africa, India, Middle East, USSR (south-east)
Thread worm	Strongyloides stercoralis	Man-man	Warm,wet climates

Infectious diseases related to water may be divided into four groups (3).

I. Water-borne (direct infection)

Viruses e.g. infectious hepatitis

Bacteria e.g. cholera, typhoid and paratyphoid fevers, bacillary dysentery, gastro-enteritis, leptospirosis

Protozoa e.g. amoebic dysentery

II. Water-washed (indirect infection and often associated with lack of personal and domestic hygiene)

Viruses, bacteria and protozoa included in Group I.

III. Water-based

Leptospirosis (ingested or by penetration of skin and mucous membranes)

Schistosomiasis (intermediate host, the snail; immature worms enter the body by ingestion or through skin and mucous membranes)

Guinea worm (intermediate host-water flea- and ingested)

IV. Water-related insect vectors

Yellow fever (virus), malaria (protozoan)

The Four Mechanisms of Water-Related Disease Transmission and the Preventive Strategies Appropriate to each Mechanism.

Transmission mechanism	Preventive Strategy
Water-borne	Improve water quality Prevent casual use of other unimproved sources
Water-washed	Improve water quantity Improve water accessibility Improve hygiene
Water-based	Decrease need for water contact Control snail populations Improve quality
Water-related insect vector	Improve surface water management Destroy breeding sites of insects Decrease need to visit breeding sites

Viruses, bacteria, protozoa and other organisms that cause disease are excreted in the faeces and urine of man and animals. The specific illnesses are spread by cases and carriers (symptomless excretors) by direct infection, polluted water, sewage, sewage effluent or sewage sludge.

Two problem diseases may be especially mentioned - cholera and bilharzia:

Cholera: the seventh pandemic (El Tor variety) 1961 to date.

Bilharzia (Schistosomiasis): two lines of attach against the snail and against the embryo worm (cercaria)

Modern treatment of drinking water supplies had reduced the incidence of water-borne diseases, but in communities where it is applied without any other public health measures, there is little reduction in the incidence of the diarrhoeal diseases, in particular.

Infectivity is kept up by:-

Lack of adequate sanitation
Absence of personal hygiene
Absence of domestic hygiene
Contamination of water between collection and use
The habits of children under three years of age
Lack of sanitary control of older children

A successful water treatment can only be achieved if there is:-

(1) Simultaneous adequate sanitation in the form of excreta and sullage disposal for children as well as for adults with special attention to the very young. There is now a wide choice of methods of excretal disposal from pit latrines with a fly-proof cover to flush latrines, septic tanks and conventional sewerage (4).

(2) Control of flies.

(3) Education of the members of the community in matters of personal and domestic hygiene, bearing in mind that the water scheme will provide more water for these purposes.

(4) Community participation. A successful project may inject enthusiasm into the populace towards further improvements in the life, comfort and welfare of the community.

(5) Self-help in the form of labour and cash contributions.

Water Treatment.

Two assumptions are made:-

(1) Modern water treatment plant facilities will not be available, lack of expert and experienced work force and supplies of water treatment chemicals will not be available or unreliable or too expensive.

(2) Methods outlined below will produce a significant improvement in the quality of the water, including bacteriological quality, but not necessarily to the fulfillment of WHO International Drinking Water Standards (5).

Protection of the source from pollution

Stages of purification to improve water quality

Distribution - under constant pressure to avoid contamination of the treated water flowing through the pipes and fittings

Quality control

Maintenance of plant and fittings

Unit processes designed to remove or destroy pathogenic agents:

Storage: deposition of suspended matter, reduction in intestinal bacteria, including pathogens.

Slow Sand Filtration: efficient, simple to construct and maintain (6), (7), (8).

Disinfection: destruction of pathogenic and non-pathogenic micro-organisms; in the case of chlorine, if excess is present, prevent the re-infection of the water during use.

(Chemical coagulation and rapid filtration followed by disinfection)

In order to apply the above processes to developing countries it is necessary to divide the communities involved into rural (villages) and urban (townships).

Rural development

Groundwater source for preference; treatment, if any, the chlorine pot.

Surface water source - slow sand filtration. If the water is very turbid, then preliminary storage for sedimentation or construct an infiltration system between source and filter. Disinfection, if necessary, with the chlorine pot.

Urban development

Groundwater with chlorination by means of sodium hypochlorite solution applied by an apparatus to feed the reagent at a constant rate. If a reliable electric power source is available, a disinfection system based on the electrolysis of brine is a possibility, or the use of ultra-violet light might be considered.

Surface water. Preliminary sedimentation and storage followed by slow sand filtration and terminal disinfection (if necessary) by methods set out for groundwater above.

Coagulation and rapid filtration by terminal chlorination by means of package-type units now manufactured and available for tropical countries (USSR, Mozambique, Latin America, India).

Quality Control to determine effectiveness of the treatment:

Bacteriological quality - reason for testing for presence of normally occurring intestinal bacteria.

Residual chlorine. Absence of a positive result at a point where some residual chlorine is usually detected may mean:-

(i) some pollution has entered the system - this is serious and requires immediate attention and investigation.

(ii) The excess chlorine has been used up by biological growths within the main - less serious but should be investigated.

Conclusion.

Provision of water supplies in developing countries is visible evidence to national, international and voluntary donors that something is being done and that the money has been well spent. On the other hand, a domestic water supply project is only part of the improvement in the public health of a community; its success depends upon simultaneous activities in sanitation improvement, education in personal and domestic hygiene together with greater supervision of the habits of the children.

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Paper 1b

Virus and Its Inactivation by Chlorine

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The contamination of water by pathogenic agents has high potential to initiate outbreaks of waterborne diseases. Domestic wastewater may contain many varieties of infectious agents which are deprived principally from the intestinal tract of infected human bodies. Unless removed or inactivated, these biological agents may presumably reach water supplies and may be distributed to consummer.

These biological agents can be grouped into the following categories: pathogenic bacteria; viruses; parasites; and other organisms. A number of various factors may affect on the relative densities of the pathogens in water. Addition to the relative ability of the pathogen to survive outside its host under various environmental conditions, the state of health of the population in a given situation, the species of pathogen in prevail, the treatment method of nightsoil, the rate of tharea covered by the sewerage system and the operational condition of water treatment plants are closely related to the densities and types of species of pathogens in water. This paper is concerned solely with virus, and its inactivation by chlorine under various strength of turbidity.

The viruses most commonly found in waters and sewages are the enteroviruses (poliovirus, coxsackieviruses and echoviruses), adenoviruses, reoviruses and virus of infections hepatitis.[1),2)] These viruses multiply in the alimentary canal or pass through it with significant quantities after multiplication at other infected sites such as the respiratory regions, and may be excreted in considerable amounts in faeces.

There are many papers reported on the density of viruses found in waters and wastewaters.[1) ~ 6)] The density of viruses may vary depending on the concentration and culturing techniques employed as well as the season of the year, per capita water usage which may relate to water quality and so on.

The density of viruses in surface water is not so much due to the large dilution that might occur when a wastewater is discharged to a receiving water. For example, a virus density of 0.1 PFU per liter was reported by the examination of a water supply intake in the U.S. river.[7)] Akin et al have shown in their extensive review of existing information on viruses in water that enteric viruses have been detected in 36 percent of the samples of surface waters examined.[8)] Although mere presence may not be necessarily significant danger to man, it is believed that even very low levels of enteric virus in water may present a potential health hazard. It has been experimentally shown that ingestion of as little as one infectious tissue culture dose of poliovirus, or other enteric viruses is sufficient to infect a portion of susceptible persons.[9)]

Although the minimal infective dose for infectious hepatitis has not been known, there are ample epidemiological evidences[10)] to prove that outbreaks of this infection are caused by polluted waters, and the ingestion of a few organisms cause of infection in some persons. A striking example was the epidemic of infectious hepatitis in Delhi (1955-56), where more than 28,000 cases were identified as infectious hepatitis, with a case fatality rate of 0.9 per 1000 and an estimated total cases of 97600.

From the sanitary engineering view point, enteric viruses present a difficult problem because it has been indicated that viruses are more resistant to inactivation by natural factors in the water environment and to most water treatment processes including disinfection process than coliform.

This means that coliform tests which are commonly used for fecal contamination may not assure that water is free of potentially infectious enteric agents. It is likely that the routine vinus assays of water will be required in the future since coliform tests appear to be inadequate in certain cases.

Based on the informations[11)] obtained sofar, viruses seem to pass through conventional water treatment system which include disinfection by chlorine.

From foregoing it is clear that laboratory techniques for detecting such low levels of viruses in water as low as 1 per liter or less should be developed to test viruses in water or to guarantee the security in water quality. These techniques are still in the development stage and contain several obstacles to be overcome. Developing the methods for concentration of viruses and finding proper host cell to be used as standard cell are essential to make common use of viruse test in water. Virus assay is very complicated compared to coliform test. The complexity mainly comes from the time-consuming concentration process and the difficulty of culture techniques of the host cell. Another problem arises from the fact that it usually takes five days or more before the results of a virus assay of water can be obtained.

The survival of viruses in water has been investigated. It is well known that viruses show no growth and no autodegradation outside the host cells. The reduction rate of viruses in water depends on the type of viruses and various environmental factors such as temperature, light intensity, pH organic content and so on. Some reports have shown that viruses survived in the river water for more than 100 days, and others could not defect viruses in the water at three or four days after inoculation of viruses into the waters.[8),12)] Figure 1 shows the result of our experiments in which poliovirus 1 was kept in distilled water. Virus titer determined by Hela-cell as Host decreases in the order of 3 log per 5 days. The decrease in titer follows the empirical relationship:

$$N = N_0 (10)^{-kt}$$

where N = Virus concentration in water (PFU/ml)
N_0 = Initial virus concentration in water (PFU/ml)
K = Rate constant

The constant K was 0.625/day at 20°C for the experiments as shown in Figure 1. This rate constant is very close to the figures found for autolysis of coliforms and activated sludges.

The informations on the inactivation of viruses have become available. The excellent studies have focused on the inactivation by chlorine.[12)~24)] Since the treatment processes, such as coagulation, sedimentation and filtration, are not likely to produce a rirus-free product, the last line of defense against pathogens before water is supplied is the final stage disinfection. The treatment processes can remove many substances that interfere with effective disinfection, but will not remove all of them. Operating and maintenance conditions affect the removal efficiency.

Chlorine is the most widely used disinfectant for water in the world. The values of pH effect markedly on the reactivity of either micro organisms or the disinfectants, or both.

The solution of chlorine ($C\ell_2$) in water is characterized by the following equilibrium equations

$$C\ell_2 + H_2O \rightleftharpoons HOC\ell + H^+ + C\ell^-$$

$$HOC\ell \rightleftharpoons H^+ + OC\ell^-$$

At ordinary water temperatures, the hydrolysis of chlorine is essentially complete within a few seconds. The relative distribution of $HOC\ell$ and $OC\ell^-$ at various pH values is calculated as follows

$$\frac{[HOC\ell]}{[HOC\ell]+[OC\ell^-]} = \frac{1}{1+[OC\ell^-]/[HOC\ell]} = \frac{1}{1+Ki/[H^+]}$$

where Ki = ionization constant
parenthesis indicates the molar concentration

For example, at pH 6 and 10, the percentage distributions of $HOC\ell$ at 20°C are 97.6% and 0.4% respectively. It is well known that the $OC\ell^-$ ion is a relatively, poor bactericide and the bactericidal efficiency of free available chlorine residual decreases significantly as the pH rises.

Figure 2 indicates that polio I is inactivated and reduced by free residual chlorine at pH 6.3 at which hypochlorus acid dominates. The reduction of virus titer in the order of 3 log PFU/mℓ could be achieved within 15 min after chlorination with dose rate of 0.1 and 1.0 mg/ℓ.

The experiments with same experimental conditions as shown in Figure 2 except pH value were performed at pH 10.0 at which the most chlorine will consist of the phpochlorite ion ($OC\ell^-$). In those cases, the reduction of poliovirus 1 within 15 min was less than 3 log PFU in the order, and more than 99.9 percent reduction of virus titer could not be achieved withir even 30 min after chlorination.

Results of these experiments (Fig. 2, 3) show that the hypochlorus acid (HOCℓ) inactivates viruces many times as rapidly as hypochlorite ion ($OC\ell^-$) as shown in reduction of bacteria by chlorine. It goes without saying that higher the concentration of chlorine, more rapidly viruses are inactivated. But, at the dosage of chlorine which is usually applied under ordinary operations in water supply, the initial dosage of chlorine is not critical on the reduction rate of viruses.

One of the important factors which exert influence on the efficiency of chlorination is amount of the suspended solids in which viruses can be embedded. The effects of such solids on chlorination have been studied by Carlson et al[25] and others.[26)~29] However, there are few reports that deal with the effects quantitatively.

The effects of particles on the inactivation of poliovirus 1 caused by hypochlorous acid are shown in Figure 4 and 5. In the case of Figure 4, inorganic particles (Kaolin) are utilized as suspended solids. Autoclaved activated sludge was used at the experiments shown in Figure 5. It is obvious from these figures that the virucidal efficiency of chlorine is affected considerably by suspended solids. Higher the concentration of suspended solids, more depressed the disinfective power of chlorine is.

When the concentration of inorganic suspended solids is 10 mg/ℓ, initial residual chlorine of 1.0 mg/ℓ is not enough to get more than 99.9% viral reduction with a 30 minutes contact times. It was impossible to obtain the reduction of more than 90.0% within 30 minutes after chlorination at pH 10.0.

Because chlorine is consumed markedly by organic substances, the inactivation of viruses in the presence of organic suspended solids (Fig. 5) may be influenced by a significant reduction of chlorine concentration in addition to the embedded effect. Virus titers in Figure 5 decrease rather quickly until 15 min after chlorination, but not faster than the experiments without turbidity (Fig. 2). However after 15 min virus titers do not decrease significantly and the inactivation rates reach to the level of less than 98% with a 30 minutes contact times.

It is well known that combined chlorines such as monochlorine, dichloramine and organic chloramine are slower to kill microorganisms than free chlorine residual. Considering the available informations, viruses would have more resistance to combined chlorines than bacteria.[14),18),29)~31] Therefore, higher concentration of combined chlorine would be required to get the same effect as free chlorine residual. The 99.9 percent inactivation of poliovirus 1 in settled wastewater was reported with a 30 minutes contact time and a combined chlorine residual of 30 mg/ℓ.[16] In another study, it was shown that only 50 percent or less of poliovirus 1 was inactivated with a combined chlorine residual of 1 mg/ℓ and a contact time of 30 minutes.[32]

It was reconfirmed in our experiments that combined chloramines have a considerably reduced power for inactivating virus and that a measurable inactivation occurs in the first few seconds before the free chlorine has completed its reaction with ammonia. For example, when chloramines existed initially with 9.0 mg/ℓ in concentration, a reduction of approximately 2 logs was expected within 15 minutes after chlorination and a reduction of less than 1 log took place in the second 15 minutes.

It may be concluded from these results that waters used for water supply must be conserved carefully not to be polluted by the domestic wastewater and other wastewater.

It might be noticed that the usage of a large dosage of chlorine in waters with high organic-content might result in the production of the carcinous trihalomethanes which can be produced by the reaction of chlorine with some organic compounds.33)

Summary

Although coliform test gives a good index for feacal pollution, some indices which indicate the contamination of viruses will be expected to be established, since viruses seem to behave in natural environment and respond to treatment operations including chlorination in the rather different ways than bacteria.

Based upon observations made by ous and others it would be concluded that the turbidity should be as low as possible to produce pathogens-free water. Suspender solids in waters must be removed before chlorination to reduce the concentration of the solids to the level at which the disinfection process, ex. chlorination and ozonation, can perform effectively their own functions. It may be concluded that the concentration of suspended solid in supplied water is desirable to be less than 1 mg/ℓ. Some investigators has been concluded that the enteric viruses can be effectively destroyed by a free residual chlorine of 1.0 mg/ℓ, provided the contact time is more than 30 minutes. The results of our experiments also show that the high concentration of free residual chlorine is essential to provide safe water. The concentration of free residual chlorine required to complete disinfection depends on the concentration and composition of the suspended solids. When waters contain 1.0 mg/ℓ of suspended solids at pH 6, more than 1.0 mg/ℓ of free residual chlorine would be required. Lower the terbidity, less the concentration of chlorine is required.

Hypochlorite ions which dominate at higher pH and combined chlorines which are apt to be produced in polluted water are not the efficient virucidal agents.

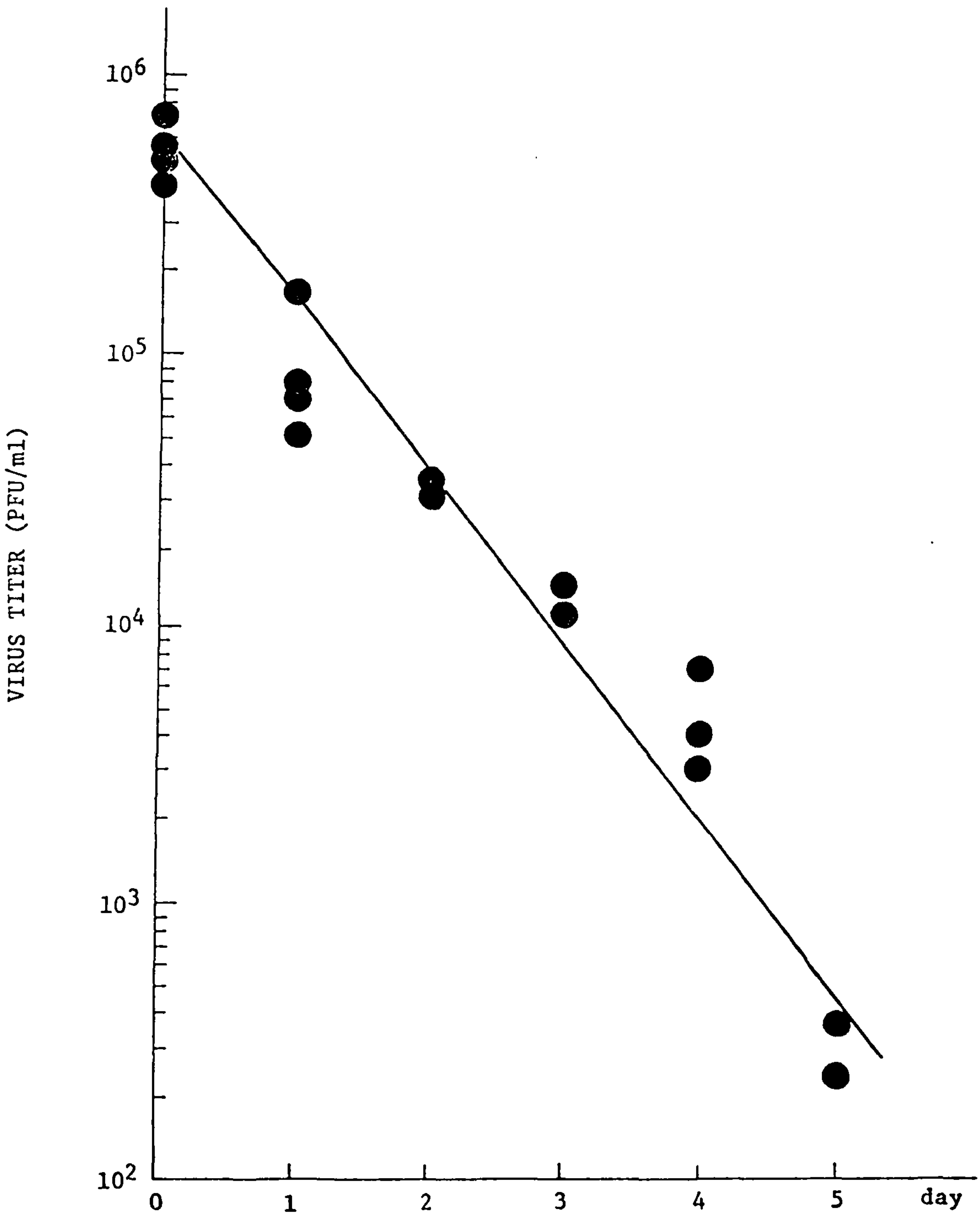

Fig. 1 INACTIVATION CURVES FOR POLIOVIRUS 1 (LSc) IN DDWs AT 20 ± 0.5°C

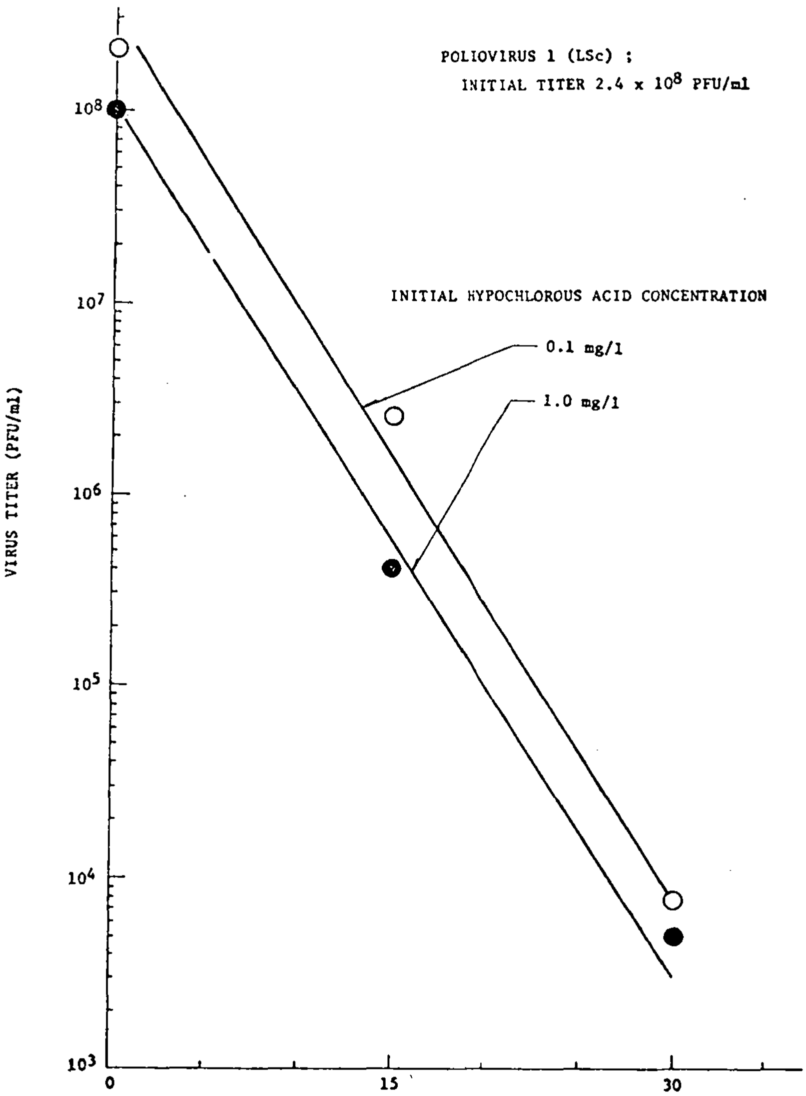

Fig. 2 INACTIVATION OF POLIOVIRUS 1 (LSc) BY HYPOCHLOROUS ACID AT 20 ± 1.0°C (pH 6.3)

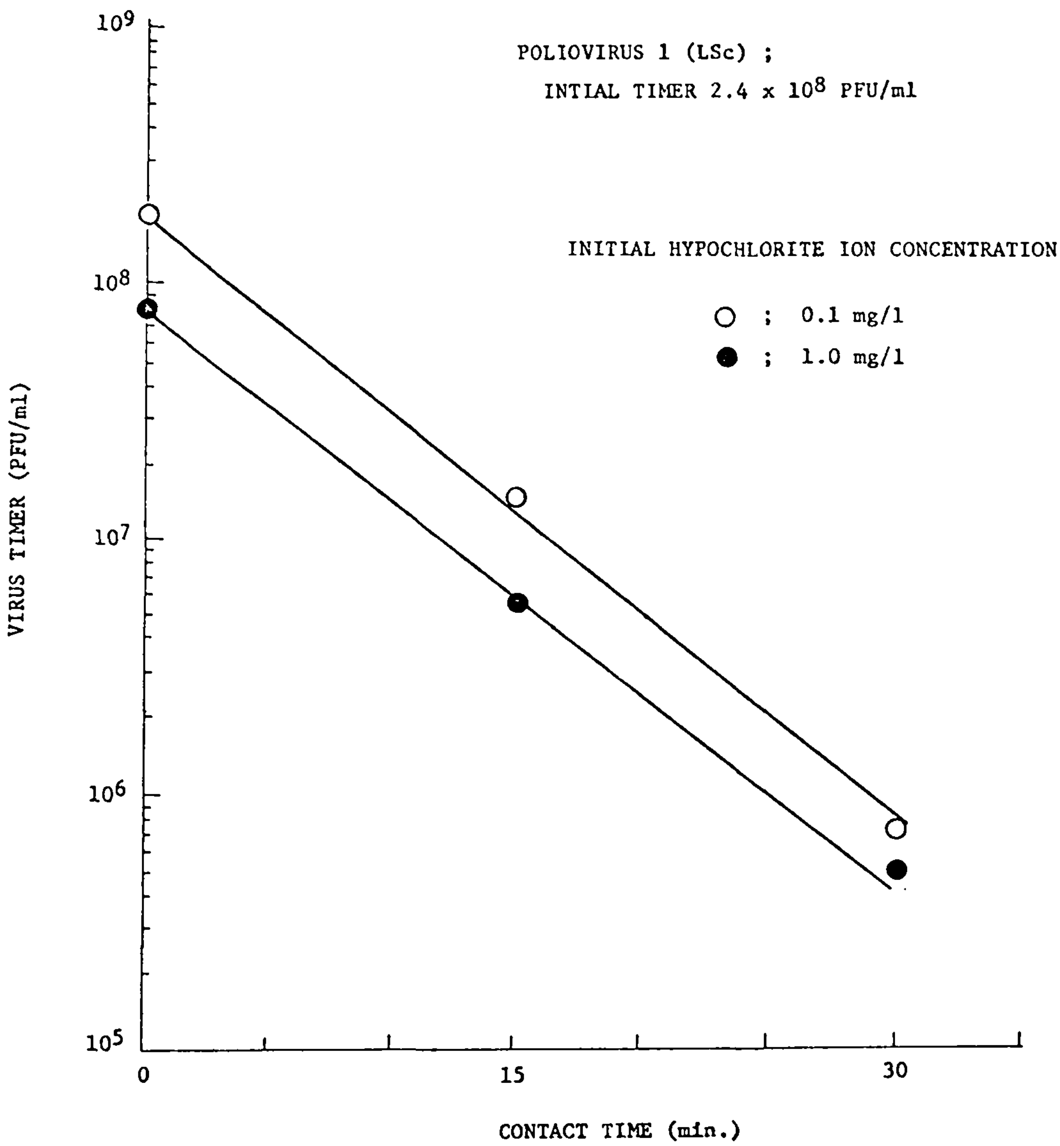

Fig. 3 INACTIVATION OF POLIOVIRUS 1 (LSc) BY HYPOCHLORITE ION AT 20 ± 1.0°C (pH 10.15)

1b10

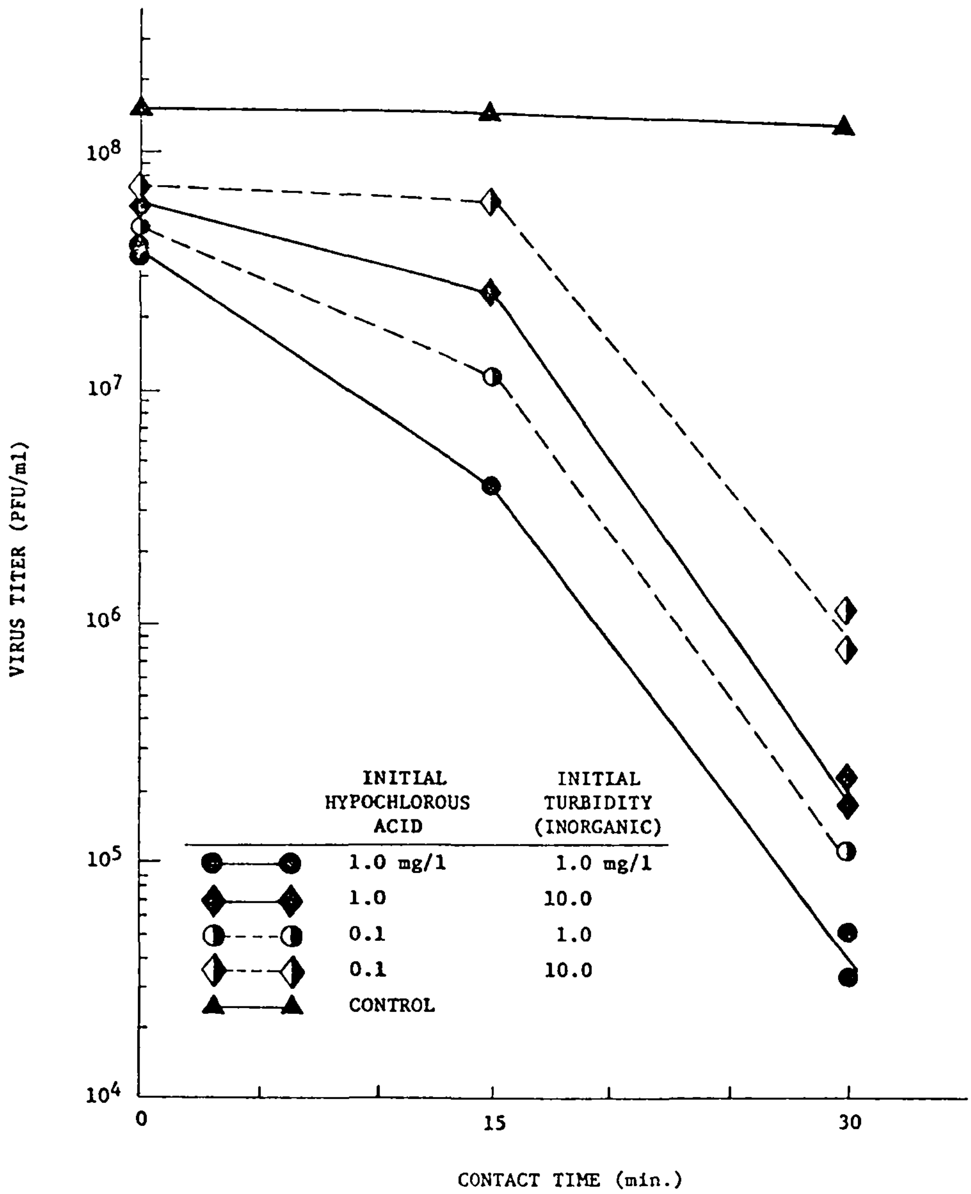

Fig. 4 INACTIVATION OF POLOVIRUS 1 (LSc) BY HYPOCHLOROUS ACID AT 20 ± 1.0°C (pH 6)

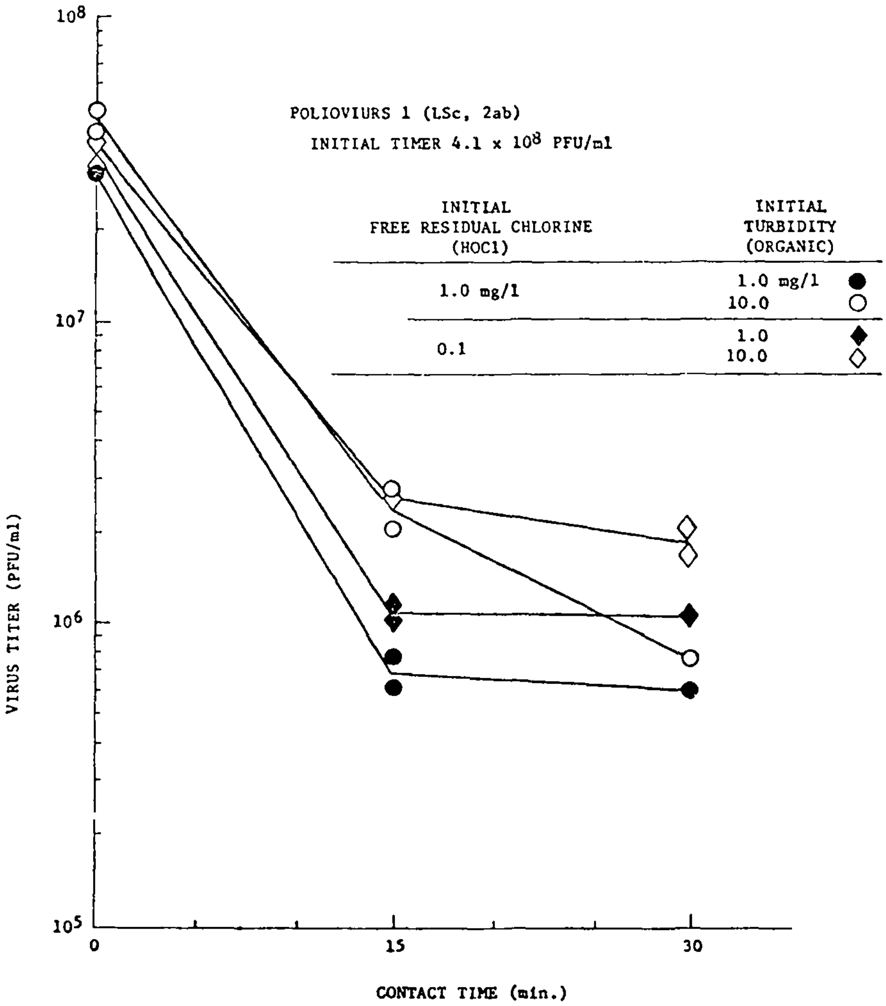

Fig. 5 EFFECT OF ORGANIC TURBIDITY ON INACTIVATION OF POLIOVIRUS 1 (LSc, 2ab) BY FREE RESIDUAL CHLORINE (HOCL) (pH 6)

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Paper 2a

Water Consumption as a Design Criterion

by A. C. Twort

Present major confusions in reporting consumption

1.1 The value of many published statistics of water consumption is reduced by frequent failure to define the basis on which the figures are quoted. Two principal defects are failure to indicate the level of leakage and wastage included in the figures, and failure to quote trade and industrial consumption separately from domestic consumption.

1.2 As a result the engineer is faced with statistics of the kind shown in Figure 1 which are of little value for design purposes.

1.3 There are also many confusions of interpretation. This is particularly so in respect of quoted figures for "losses" which, in fully metered systems include only distribution system losses upstream of consumers' meters, and in unmetered systems may include also wastage and leakage on consumers' premises.

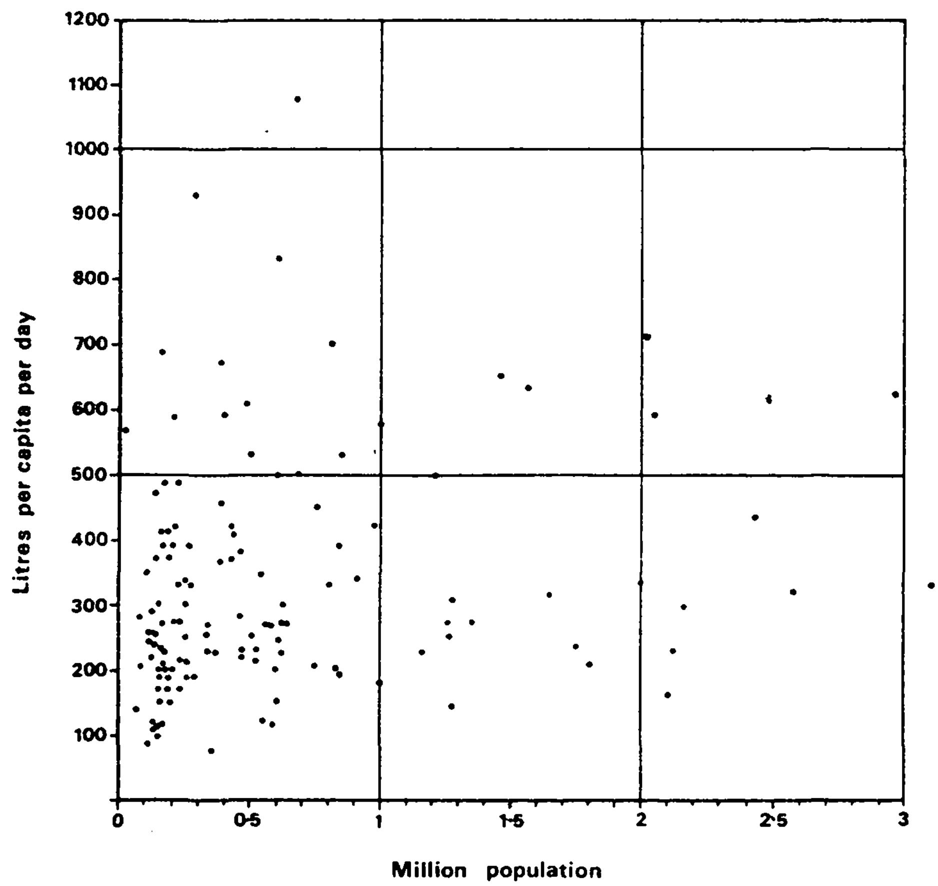


Figure 1. Average daily consumption in 130 towns in Europe, Asia, Russia, South Africa and the Americas in 1969. (Ref. 1.)

Some proposed definitions

2.1 Quoted quantities of water come in three classes:—

(a) measured (Qm) by some meter or meters;

(b) 'estimated' (Qe) by some means which are intended to be as accurate as possible in the circumstances;

(c) 'derived' (Qd) being figures showing the quantity that remains after (a) and (b) have been accounted for.

2.2 For proper comparison between metered and partly un-metered systems we have to ensure that estimates of Qe are made on the same basis as if they were measured values Qm. That is, estimates Qe must refer to the same portion of the distribution system as if consumers' meters were installed.

2.3 On the foregoing basis a diagram of the terms proposed for clarity is shown in Figure 2. These terms may not be wholly satisfactory and are put forward for discussion.

2.4 The definitions suggested are as follows:

consumption – the amount of water actually supplied (or estimated to be supplied) for some purpose.

demand – the amount of water estimated to be required for some purpose.

*gross consumption (*or *gross demand)* – consumption (or demand) inclusive of distribution losses.

unsatisfied demand – the amount of demand which is in excess of available supply.

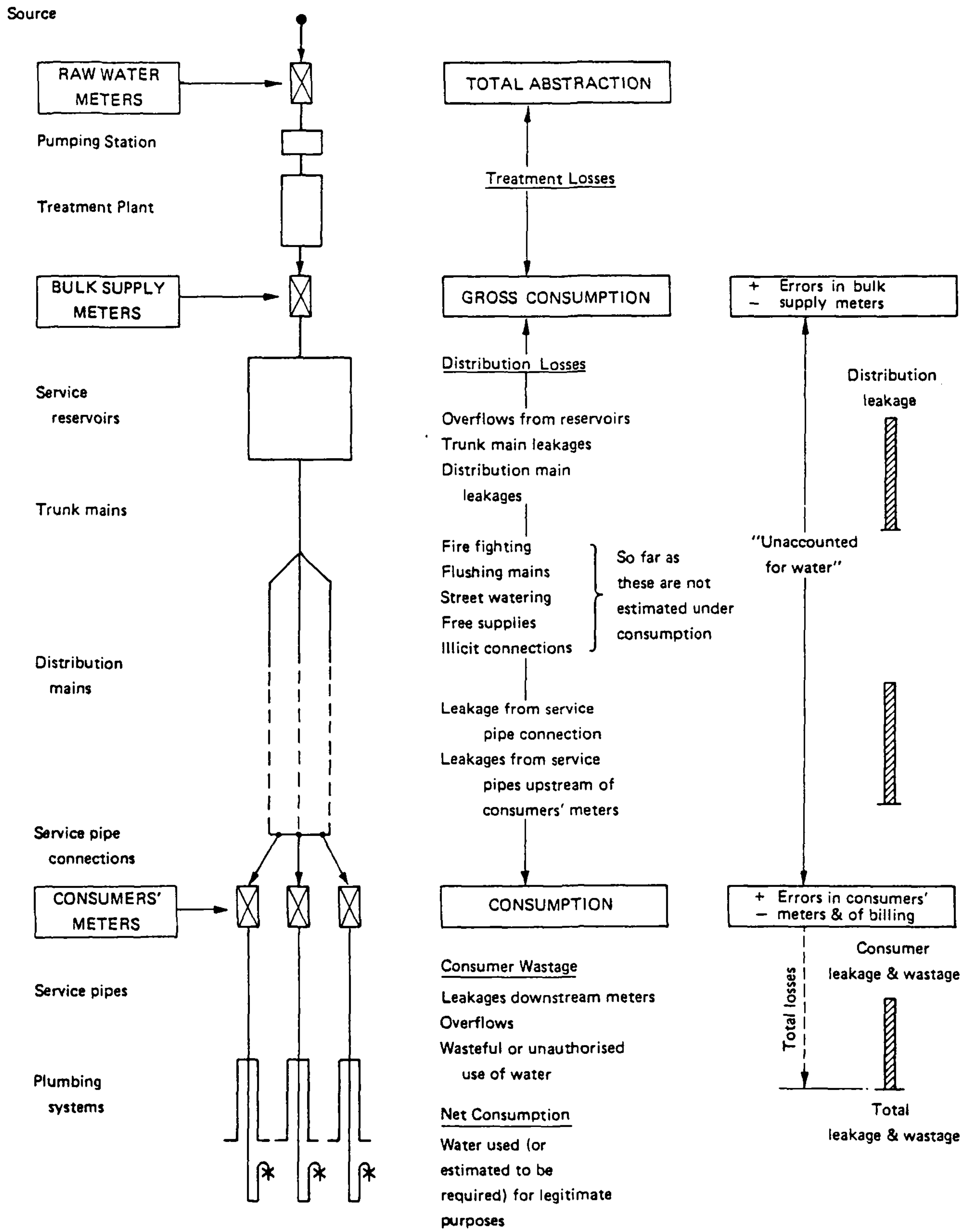
losses – a general term which includes all leakage and wastage and all supplies not accounted for.

unaccounted for water – (specifically) the quantity difference between readings of the bulk supply meters and the summation of readings on consumers' meters.

– (generally) all water which is not accounted for separately.

distribution losses – comprising two parts (1) 'distribution leakages' from mains, valves, service pipe connections etc. and (2) unmeasured supplies such as for fire fighting, flushing mains, etc.

consumer wastage – leakage, wastage, and wasteful use on consumers' premises, downstream of the supply meter or (if there is no meter) downstream of the point at which a meter would normally be installed.



Term as above	Alternative terms
"GROSS CONSUMPTION"	"Total Consumption including distribution losses"
"CONSUMPTION"	"Total Consumption excluding distribution losses"
"Net Consumption"	"Net Consumer demand" (or consumption).

Terms for Water Consumption
FIG. 2

Categories of consumption

3.1 There is a need to define categories of water usage accurately. Each category must comprise a water usage that can, where necessary, be identified and quantified, both now and in the future.

3.2 The categories most likely to prove useful in practice are set out in Table 1.

Table 1

Suggested categories of consumption (or demand)

Category of Use	Other usages which should be stated if included
(i) **DOMESTIC or DOMESTIC & SMALL TRADES** Use in households for – drinking, cooking, bathing, laundering (including washing machines), cleaning, sanitation, car washing, hosing yards.	(i) garden watering (ii) air conditioning (desert coolers) (iii) small trades to the level normally occurring in urban areas.
(ii) **INSTITUTIONAL & MUNICIPAL** Hospitals, schools, government offices, military establishments and similar (in excess of that allowed for under Small Trades). Municipal use for gardens, street watering, sewer cleansing, etc.	(i) street watering (if large) (ii) public garden watering (iii) air conditioning in establishments (desert coolers).
(iii) **COMMERCIAL** Shops, offices, hotels and similar (in excess of any allowance under Small Trades)	(i) air conditioning (desert coolers).
(iv) **INDUSTRIAL** Factories, industries, port supplies, railways, etc.	
(v) **AGRICULTURAL** For cattle milk production, horticulure, etc.	State predominant types.
(vi) **BULK SUPPLIES GIVEN** The quantity given should be quoted separately	(The amount should be deleted from all per capita analyses).
(vii) **DISTRIBUTION LOSSES** The allowance for distribution leakage and for all other 'un-metered free supplies' which have not been allowed for under (i) to (vi) above	(Expressed as a % of the Total Gross Consumption) i.e. as a % of the total of (i) through (vii)).

Accuracy of domestic consumption tests

4.1 To measure domestic consumptions per capita accurately the following conditions have to be fulfilled:–

(i) The supply must be a 24 hour supply under reasonable pressure, and must have been so for a considerable period before the test.

(ii) The supply must be accurately metered to each household for the whole period of test.

(iii) The number of persons in each household over the whole period of test must be accurately known.

(iv) There must be no leakages downstream of the point of measuring flows.

(v) The period of test must be long enough to even out day to day fluctuations of demand due to the variation in habits of each household.

(vi) The sample of households chosen for testing must be as 'true' a sample as possible of the whole of the class represented.

(vii) The classes of house chosen must be definable in terms which can be used to identify similar classes of households elsewhere and in the future.

4.2 It is not possible to comply with all the foregoing requirements in every case; but requirements (i), (ii) and (vii) must apply if the results are to be of any use.

The principal problem is that if reasonably 'true' samples (vi) are to be obtained, then the sample size has to be large, and the time of testing (v) has to be long. In practice neither of these things is possible without sacrificing some accuracy in respect of meters (ii), the number of persons in each household (iii), and the amount of leakage (iv).

4.3 **Three grades of test accuracy** apply to quoted figures of domestic consumption.

Accuracy Grade	Defects
Grade I Accuracy	
Field measurements, using tested meters, of actual flows to individual households with the number of persons served being counted in each household. Properties with apparent leakage or excessive use eliminated.	Cannot be conducted for many households or for a long period. Hence the mean of the sample results may depart from the mean for the whole class represented.
Grade II Accuracy	
Selective analysis of meter records coupled with counting number of persons served in each case; or estimating number of persons served.	Figures include an unknown amount of consumer wastage. Meters are assumed to be accurate but this may not be true.
Bulk measurement of flows to an estimated population using a tested meter, the distribution system downstream of the meter being prior tested for leakage.	Figures include an unknown amount of consumer wastage and distribution losses downstream of the bulk meter.
Grade III Accuracy	
Indicated total supplies over a period to an estimated population.	Figures include bulk supply meter errors, distribution losses, consumer wastage, and supplies to small trades.

Test results on domestic consumption

5.1 Despite the difficulties mentioned above an increasing number of field tests of Grades I and II accuracy have been undertaken of recent years. Those known to the author are given in Table 2.

More field data of this type would be valuable; but it is important that all tests comply with the conditions listed in para 4.1 above, and that the type of household is precisely described.

5.2 **For identifying classes of household** the following classification of dwellings is suggested:–

high class	–	villas, detached houses, luxury flats occupied by high income households – having 2 or more WCs and 3 to 4 (or more) taps per household.
middle class	–	all flats and houses occupied by middle income households – having at least 1 WC and 2 taps per household.
lower class	–	tenement flats; government subsidised block housing occupied or shared by lower income groups (above the poverty line) – having at least 1 tap per household but sharing a WC between two or more households, or having Asian type toilets.

5.3 It may not be possible to adhere strictly in every case to the classifications given above when analysing reported consumptions. To some extent relative income and relative standard of housing must be taken into account.

5.4 The figures for net consumption in middle class housing given in Table 2 support a basic finding as follows:–

> **for middle class households with a 24 hour supply the mean consumption per capita (exclusive of consumer wastage and garden watering) is about 115 lcd irrespective of country: with a range of + or – 15 lcd in particular cases.**

5.5 Departures from the above figure always relate to special circumstances. For example the lower figures reported from Mansfield relate to a town having little new development; the Cairo higher figure of 149 lcd relates to new city flats of a generally superior class occupied by relatively wealthy people. The higher figures for upper middle class consumption in Palembang, Alexandria and Port Said all include some amount of consumer wastage.

Table 2

Grades I & II test measurements of domestic consumption

Accuracy Grade (Sample Number)	Location and Year		Housing Class					Notes
			High		Middle		Lower	
			Income Class					
			High	Average	Upper	Lower	Low	
ENGLAND								
I (461)	Mansfield	1976	150	117	105	72		(1)
I (392)	Malvern	1976	126	115	115	89		(2)
I (977)	South West	1976	131	---- av.	103(U) ----			(3) Winter
	South West	1976		---- av.	106(R) ----			figures
	South West	1976		---- av.	111(C) ----			only
II (2626)	East Anglia	1977	136	125	126	114		(4)
OVERSEAS								
I (192)	Istanbul (Turkey)	1975	175		-----116-----		56	(5)
I (48)	Sakaka (Arabia)	1975			120	110	70	(6)
? (?)	Lesotho (S. Africa)	1976		161	121	107		(7)
II (56)	Cairo (Egypt)	1976	260		149		70-55	(8)
II (17)	Palembang (Indonesia)	1970		204	152			(9)
II (1351+)	Hong Kong (Asia)	1977	182	127	127	97	52-47	(10)
II (38)	Alexandria (Egypt)	1976	180+		130	100	70-55	(11)
II (17)	Port Said (Egypt)	1978	248		155		50	(12)

Notes to Table 2

(1) 150 – highest social group; 117 – detached houses; 105-72 other houses.

(2) 126 – highest social group; 115 – detached houses; 115-89 other houses.

(3) 131 – for 'high consumption households'; U = urban; R = rural; C = city of Plymouth; "av" = average representative sample of high and middle class housing.

(4) Figures are for 8 separate urban areas. 136 is for detached houses and the 125 for mixed semis and detached houses. All figures are inclusive of the night flow line.

(5) In very high class properties consumption was 260 lcd.

(6) The 120 applies to compounds: the 110 to new flats.

(7) The figures quoted are averages for total households having plumbing systems in three towns, the classes of housing not being distinguished.

(8) 260 lcd refers to luxury class flats or villas having an average of 6 taps and 2.2 WCs per household and an average occupancy of 6.1 persons. 149 lcd refers to new middle class flats having an average of 4.4 taps and 1.3 WCs per household with an average occupancy of 5.4 persons.

(9) Both figures refer to detached houses. Consumer wastage is included in the reported figures. Also some use of taps by outsiders.

(10) 182 lcd refers to luxury class flats, block metered. 127 lcd refers to individually metered private flats occupied by middle or high income groups. 97 lcd refers to individually metered private flats occupied by middle and low income groups. 52-47 lcd refers to Government low cost houses with 1 WC and 1 tap per household, with each household individually metered.

(11) Figures are from a plot of consumptions (from billing records) for 7 separate grades of income.

(12) Figures are from billing records classified into 'high', 'medium' and 'low' consumptions after excessive consumer wastage (as observed and varying from 14% to 46% of the total billed) was deducted. In all cases there was block metering.

Design criteria for domestic consumption

6.1 The point of most interest revealed by Grade I tests is that, when consumer wastage is eliminated, middle income householders in middle class dwellings appear to consume about the same average amount per capita irrespective of country and climate. The mean consumption of 115 lcd is reflected in figures from UK, Hong Kong, Istanbul, Sakaka (a desert oasis town in Arabia), Alexandria, and small towns in Lesotho.

We can use this information with advantage to set up design consumption figures for general use.

6.2 In the first instance, however, it must be noted that the figure of 115 lcd for middle class households derived from the field tests excludes consumer wastage because the tests were on selected properties with no evident wastage.

Design figures for large domestic populations must be higher than field test results to allow for an unavoidable amount of consumer wastage that must be occurring at any given time when the supply to large numbers of households is under consideration.

6.3 Also, because a very simple classification of households has been taken, the design figure for a whole urban area must vary slightly according to whether the standard of housing in that area is generally high, or generally low.

6.4 A third factor that must be allowed for is whether consumers are individually metered (and billed), or whether there is block metering – i.e. one meter installed to a block of households.

6.5 **Criteria suggested.** Taking the foregoing factors into account and noting the special circumstances attached to each test result quoted in Table 2, the design criteria in Table 3 are suggested.

Table 3

Suggested Domestic Consumption Design Criteria

Household type	Design demand (including a reasonable allowance for unavoidable consumer wastage)
individually metered:-	excluding garden watering:-
(i) **Middle class** dwellings	**145 lcd** mean. 150 lcd for newer or above average dwellings. 140 lcd for older or below average dwellings.
(ii) **High class** dwellings	**180 lcd** as a reasonable overall mean. **250 lcd** for 'luxury class' dwellings
block metered supplies:-	
(iii) **Lower class** dwellings	**110 lcd** which allows for 35% to 55% consumer wastage in block metered premises.
Mixed residential areas.	
(iv) For typical large mixed residential areas	**145 lcd** overall mean. (This allows for about 20% high class dwellings and 30% lower class dwellings).

6.6 The figures in Table 3 also include a small margin for local distribution losses.

The additional distribution losses to be added are considered under para 10.7.

Multi-variate analyses of consumption

7.1 Many attempts have been made to obtain correlations between consumption and such variables as – number of persons per household; type of house; age of house; income of householder; number of fittings per house; incidence of washing machines, dishwashers etc. But, as Thackray (Ref. 2) reports attempts to isolate these factors are made difficult because of the wide variations of per capita consumption from house to house within the same class.

7.2 It is also obvious that many of the variables are not independent, but interdependent, since income is a major determinant of type of house occupied, and the type of house determines the number of fittings per household etc.

7.3 But the chief objection to such analyses for the purpose of estimating future demand in any particular case is that they require a greater knowledge of the dependent variables in the future than is practicable.

Size of house, number of fittings per house, number of occupants per house, the occupants' income, and what percentage of washing machines occur, etc. are all 'economic' factors which are as difficult to predict as the economy of a country itself.

Practical forecasting

8.1 In its simplest form domestic water consumption depends mainly on two factors –

(i) the standard of housing occupied;
and (ii) the method of charging for water.

8.2 The standard of housing itself reflects many of the other factors such as income of householder, number of fittings, incidence of washing machines, etc. and also the water-consuming habits within the household.

It is important, however, to give clear descriptions of 'housing class' and it is for this reason that the simple division given in para 5.2, subdivided at most into the categories shown in Table 2, has been put forward.

8.3 Using quite 'rough' data concerning expected changes of population in each income group, coupled with rough estimates relating to housing developments, forecasts of a reasonable standard of accuracy can be made with respect to domestic demand.

In this connection it can be pointed out that the consumption by low income consumers in low class housing does not need to be appraised with such accuracy as the forecast for middle class consumers, because every community plans to diminish the low income class and their total current consumption (which should be ascertainable from records) will not normally increase.

8.4 The method of charging for water is important, not for its influence on net consumer consumption, but for its influence on consumer wastage.

Figures from both Hong Kong and from Istanbul (Ref. 3) – and no doubt from many other authorities – clearly show that block metering is ineffective in curbing consumer wastage. With shared facilities, as in low class housing, it is of course impossible to avoid block metering: but Hong Kong's experience shows that it is practicable to adopt individual metering for even the lowest class of new housing if each household has a separate supply pipe.

8.5 As regards the level of charges made for the water it is the presence of an individual meter, rather than the charge made for water, which curbs consumer wastage.

The price-elasticity of the demand for water (exclusive of garden watering) is well known to be low (Ref. 4). In practice it is zero for the lowest income groups (since charges to them are purposely made 'notional') and it is virtually zero for the upper middle and higher income groups where the cost of water is not high enough relative to income to be of any consequence.

Growth of domestic consumption

9.1 The growth of domestic consumption per capita year by year under static housing conditions is difficult to assess as no clear statistics have been provided.

9.2 One of the principal findings of recent house to house surveys conducted in England is that the net consumption of middle class consumers has a current mean of 115 lcd. This figure represents 25.3 imperial gallons per head per day – a figure which is no more than was quoted for typical domestic consumption in England in the 1920s and 1930s.

9.3 Growths of about 3 lcd per annum in total domestic demand have been mentioned in recent years, but this figure must necessarily include the increase due to increased standards of housing. The rate could not have applied for any length of time past or unacceptably low figures would be predicated for a decade or two ago.

9.4 Clearly therefore the basic growth rate of domestic consumption, exclusive of the effect of increased housing standards, is some relatively low figure. In practice, however, it need not be assessed separately if reasonably liberal provisions have been made for the effect of better housing conditions in the future.

A new approach to leakage and wastage

10.1 The figures show that, if avoidable consumer wastage is eliminated, we can assess domestic demand with a reasonable degree of accuracy using figures of the type given in Table 3 above.

10.2 We can then add to this domestic demand the total metered demand of supplies to institutions, commerce, industry and agriculture and so arrive at a fair measure of what the total demand to a given supply area should be excluding:–

- (a) water used by domestic consumers for garden watering;
- (b) seasonal usage by visitors;
- (c) consumer wastage in excess of that allowed for;
- (d) distribution system losses;
- (e) other supplies which are not metered.

10.3 It is not difficult to ascertain (a) above by inspection of records in any particular case; and it is not difficult to assess the water consumption effect of (b) though it is often difficult to assess the numbers of visitors. In respect of (e) – the total consumption for such matters as fire fighting, washing out mains, building supplies taken from firehydrants etc. – the amount involved is relatively small. Where large 'free' supplies are given for watering public gardens, or as supplies to government or other establishments, the quantity is ascertainable by inserting meters, even if such meters are used only for record purposes and not for charging.

10.4 As a consequence it is possible to build up the total supply that a community requires, based partly on what is metered and partly on what is known to be reasonable amounts for domestic purposes and miscellaneous supplies. The amounts for domestic purposes should be regarded as 'allowances', representing the quantity of water which, if properly delivered to consumers, should prove adequate for their needs. (Where not all consumers get this allowance because of low pressure, intermittent supplies etc., then adjustment of the computation must be made, substituting what consumers actually receive for what they should receive).

10.5 It follows that the difference between total demand so estimated and the amount actually put into the system represents –

excessive (or avoidable) consumer wastage;
under-billing or under-reading of consumers' meters;
'free' or illegal supplies under-estimated;
distribution leakages.

The foregoing represents the 'unaccounted for water' in the general sense defined in para 2.4 above.

10.6 However, instead of quoting the unaccounted for water as a proportion of the total water produced, it would be better to quote the "efficiency of the distribution system" where –

$$\text{Efficiency} = \frac{\text{total water accounted for}}{\text{total water produced}} \times 100\%$$

10.7 There is increasing evidence that distribution efficiencies of 80% to 84% represent reasonably satisfactory performances for total supplies to large urban areas of half a million population upwards (Ref. 5).

For small distribution areas or for small portions of areas, distribution efficiencies of 90% to 95% should be achievable.

But where there is a backlog of work to be done in respect of leak detection, maintenance of meters, prevention of illicit connections, reduction of consumer wastage, and improvement of billing procedures, figures of only 45% to 55% efficiency are reported.

10.8 The use of figures for distribution efficiency percentage is more constructive than that of quoting losses. Reduction of unaccounted for water is a constructive task, crucial to the health and prosperity of a water undertaking.

Staff engaged on this work, now called 'waste inspector' or 'waste engineer', ought to be retitled – "Distribution Efficiency Improvers", or "Distribution Efficiency Engineers".

When new sourceworks are to be constructed the efficiency of the related distribution system should be taken into account. To build new works to feed a system which may be only "50% efficient" highlights the financial importance of distribution efficiency.

General

11.1 The foregoing material has been put forward only as a basis for discussion. Different assessments and different figures are always possible but it is hoped that those quoted will be found generally in line with common experience.

11.2 I am grateful to many authorities for receipt of figures quoted and acknowledge assistance and permission from Binnie & Partners in publishing this paper.

A.C. Twort

References and Notes

Reference

(1) "Demand for water in towns 1969-1990" Janczewski H. IWSA Congress 1974.

(2) "The Malvern and Mansfield studies of domestic water usage" Thackray J.E.; Cocker V.; Archibald C. Proceedings ICE Part 1 Feb. 1978.

(3) Hong Kong : private communication. Figures showed 111 lcd in low class low income flats where block metering occurred with shared washing facilities; whereas with individual metering of households consumptions in the range 47 to 52 lcd were reported. In Istanbul test results gave –

Under	15 persons/meter	90 lcd average
15 to	35 persons/meter	144 lcd average
Over	35 persons/meter	233 lcd average.

(4) "The Inelastic Demand for Residential Water : New Findings". Camp R.C. Journal AWWA Aug. 1978.

(5) Private communication IBRD. Generally speaking 84% efficiency can only be obtained on an old large system after energetic waste detection measures have been applied. It can only be kept down to this figure by continued energetic measures.

Paper 2b

Future Prediction of Water Demand

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1. Introduction.

It is said that the present generation will have to concentrate much of its efforts on the problem of water supply. In fact, all over the world nations are now confronted with a shortage of water. This tendency will become more serious day by day. For instance, the United States of America, which is defined as a heavy consumer of water, has forecast that consumption of water will grow threefold over the next three decades. According to statistics in Japan, the amount of water consumed is growing every year at the rate of about 10%. It must be noted that this rate is much larger than the economic growth rate of 7% per annum.

There are several reasons for the growth of consumption of water, such as climate, standard of living, propagation ratio of sewerage, cost of water, water quality, water pressure in the distribution system, water metering and so on. In addition to these reasons, which are the ones commonly stated, it is valuable to know that the amount of water increase will coincide with one-tenth of population increase.

Generally speaking, it is difficult to protect against the leakage of water through distribution systems up to 20%. However, the daily maximum water consumption is given by Table I including leakage of water.

Table - I Daily Maximum Demand

Population	Daily Maximum per capita per day
less than 10,000	100 -- 150 liters
less than 50,000	150 – 250 liters
less than 500,000	250 – 350 liters
more than 500,000	more than 350 liters

It is usual for daily average water consumption to be 70% of daily maximum for small and medium sized municipalities, and 80% for large and industrial municipalities.

2. Future Prediction by Standard Deviation.

In 1971, when the author was the expert for Thailand under the Colombo Plan, the future prediction of water demand was studied in the Public Works Department, Ministry of Interior, Government of Thailand, referring to annual reports of water consumption shown in Table 2.

Table - 2 Past Records of Water Consumption

	Population Estimation at 2000 AD	Water Consumption (l/c/d)							
		1959	1960	1961	1962	1963	1964	1965	1966
A	12,000	30	32	27	28	28	27	30	29
B	109,000	-	48	-	72	-	64	-	140
C	68,000	52	83	91	81	53	66	64	
D	28,000	36	77	-	93	93	104	100	114
E	28,000	39	70	77	96	53	106	104	104
F	74,000		65	81	112	56	203	200	62
G	28,000	60	66	46	47	34	46	61	67
H	13,000	103	77	70	148	76	79	142	274
I	13,000	-	49	-	55	-	122	-	-
J	60,000	86	63	58	130	56	137	200	215
K	28,000	56	50	48	48	68	82	95	-
L	172,000	-	125	-	150	-	160	-	-
M	136,000	-	114	-	68	-	75	-	113
N	100,000	-	142	-	107	-	137	-	131
O	18,000	74	59	70	93	86	88	78	108
P	46,000	-	-	-	140	-	264	-	-
Q	82,000	-	-	-	-	61	67	67	69
	-	536	1,120	586	1,468	664	1,827	1,141	1,426

Taking the whole data for 1959 for 9 municipalities, the standard deviation is computed as follows:-

Name of Municipality	Average Consumption per Capita per Day (X_1)	$X_1 - m$	$(X_1 - m)^2$	Remarks
	l/c/d			
A	30	−29.6	876.16	$n = 9$
D	36	−23.6	556.96	
E	39	−20.6	424.36	$m = \frac{\Sigma X_1}{9} = 59.6$
C	52	−7.6	57.76	
K	56	−3.6	12.96	
G	60	+0.4	0.16	$\delta = \sqrt{\frac{\Sigma (X_1 - m)^2}{n}}$
O	74	+14.4	207.36	
J	86	+26.4	696.96	$= \sqrt{\frac{4{,}716.24}{9}} = 22.9$
H	103	+43.4	1,883.56	
	536	-	4,716.24	

If the same calculation is carried out for each year from 1959 to 1966, the results in Table 3 are obtained.

Table -3 Standard Deviation

	1959	1960	1961	1962	1963	1964	1965	1966
n	9	15	9	16	11	17	11	12
m	59.6	74.7	63.1	91.8	60.4	107.5	103.7	118.0
$(X_1 - m)^2$	4,716.24	13,065.35	3,236.89	21,413.04	3,914.56	55,770.25	30,942.19	50,785.64
δ	22.9	29.5	19.0	36.6	18.9	57.3	53.0	65.1
$m - \delta$	36.7	44.2	44.1	55.2	41.5	50.2	50.7	53.7
$m + \delta$	82.5	104.2	82.1	128.4	79.3	164.8	156.7	183.9

According to Table 3, the standard deviation tends to increase year by year, which means that the differences in water consumption are increasing between municipalities consuming large amounts of water or those consuming small amounts of water. This demonstrates that the water consumption depends on the scale of municipalities, and should not be predicted using a universal formula for future estimation, throughout all municipalities.

Developing this theory, municipalities are divided into three categories: municipalities less than 50,000 population: those between 50,000 and 100,000; and those more than 100,000. Then for example, taking municipalities of less than 50,000 population, 7 municipalities (A, D, E, G, H, K and O) are picked up from the past record listed in Table 2 for 1959. Among these 7 municipalities, the mean value is determined from 5 municipalities, neglecting the maximum (H) and minimum (A) values. This gives (D + E + G + H + O)/5 = 53 for 1959. These results are shown for the period from 1959 to 1967 in Table 4 in which future demand of water is estimated by the least squares method.

Table 4 - Daily Consumption, mean value per year

Year	x	Y	X = x	x^2	XY
1959	0	53	0	0	0
1960	1	62	1.000	1	62.00
1961	2	62	1.414	2	87.67
1962	3	72	1.732	3	124.70
1963	4	71	2.000	4	142.00
1964	5	84	2.236	5	187.82
1965	6	88	2.449	6	215.51
1966	7	98	2.645	7	259.21
1967	8	99	2.828	8	279.97
Total	-	689	16.304	36	1,358.88

Considering the parabolic curve to be one of the best solutions to determine an estimate of future daily consumption, the data of Table 4 is applied for $Y = a\sqrt{x} + b$ as follows:-

$$a = \frac{n\Sigma XY - \Sigma X \cdot \Sigma Y}{n\Sigma X^2 - \Sigma X \cdot \Sigma X}$$

$$= \frac{9 \times 1,358.88 - 16.304 \times 689}{9 \times 36 - (16.304)^2}$$

$$= 17.1, \text{ say } 17$$

$$b = \frac{\Sigma X^2 \Sigma Y - \Sigma X \Sigma XY}{n\Sigma X^2 - \Sigma X \Sigma X}$$

$$= \frac{36 \times 689 - 16.304 \times 1,358.88}{9 \times 36 - (16.304)^2}$$

$$= 45.5, \text{ say } 45$$

In consequence the equation $Y = 17\sqrt{x} + 45$ is determined as the basic equation for estimating future daily consumption. The water demand for more than 50,000 population can be determined as well. Applying the same principle the equation $Y = 17X + 65$ is obtained for municipalities between 50,000 and 100,000 and the equation $Y = 17X + 90$ for municipalities of more than 100,000 population. Then, future consumption can be predicted as in the following Table 5.

Table 5 - Predicted Daily Consumption

Year	50,000		50,000–100,000		100,000	
	X	Y	X	Y	X	Y
1970	11	101	11	121	11	146
1980	21	123	21	143	21	168
1990	31	140	31	159	31	185
2000	41	155	41	175	41	200

3. Variation in Water Consumption.

In order to plan a satisfactory water supply system, it is imperative that we should know exact seasonal, daily and hourly variation of demand. However, since the condition of water supply is such that it has never met the full demand of the people, it is not possible to have an exact knowledge of such variations.

To cope with the shortage of data, several types of field study have been performed throughout developing countries. Unfortunately, however, since the water supply has been limited and restricted due to shortage of water, it has not been possible to ascertain the actual consumption per house or per capita. This tendency is always emphasized in a municipality in which such study is needed.

Table 6 shows the monthly variation of water consumption in Sri-racha, Thailand which is a small municipality having commercial activities such as a refinery and a fishery.

From Table 6 it can be seen that the maximum consumption is recorded in December or February at about 20% over the average consumption throughout the year. This may show a typical variation, especially in the water being used for domestic purposes. Therefore, when commercial use could be expected in future, the ratio between maximum and average may be larger than 1.20.

Table - 6 Water Consumption in Sri-racha

*: Assuming 7 families/meter

MONTH	No. Meter 1969	No. Meter 1970	Amount of Water 1969 (m^3/min)	Amount of Water 1970 (m^3/min)	Population* 1969	Population* 1970	Amount of Water 1969 (m^3/day)	Amount of Water 1970 (m^3/day)	l/c.d 1969	l/c.d 1970	Ratio 1969	Ratio 1970
1	1,252	1,443	45,351	49,272	8,764	10,101	1,511.7	1,642.4	172.5	162.6		
2	1,265	1,458	50,662	65,873	8,855	10,206	1,688.7	2,195.8	190.7	215.1		
3	1,269	1,476	45,019	59,609	8,883	10,332	1,500.6	1,987.0	168.9	192.3		
4	1,289	1,490	54,690	58,171	9,023	10,430	1,823.0	1,939.0	202.0	185.9		
5	1,297	1,513	47,925	64,452	9,079	10,591	1,597.5	2,148.4	176.0	202.9		
6	1,308	1,524	49,633	53,298	9,156	10,668	1,654.4	1,776.6	180.7	166.5		
7	1,328	1,566	51,506	60,505	9,296	10,962	1,716.8	2,016.8	184.7	184.0		
8	1,337	1,628	46,113	60,318	9,359	11,396	1,537.1	2,010.6	164.2	176.4		
9	1,350	1,635	46,964	58,243	9,450	11,445	1,565.5	1,941.4	165.7	169.6		
10	1,383	1,654	44,933	50,617	9,681	11,578	1,497.8	1,687.2	154.7	145.7		
11	1,399	1,683	44,041	67,714	9,793	11,781	1,468.0	2,257.1	149.9	191.6		
12	1,414	1,699	63,302	61,462	9,898	11,893	2,110.1	2,048.7	213.2	172.3		
Total	—	—	—	—	—	—	—	—	2,123.2	2,164.9		
Max.	—	—	—	—	—	—	—	—	213.2	215.1	1.21	1.19
Min.	—	—	—	—	—	—	—	—	149.9	145.7	0.85	0.81
Aver.	—	—	—	—	—	—	—	—	176.9	180.4	1.00	1.00

As well as daily maximum demand, the hourly variation of water consumption was studied, as shown in Table 7. Hourly maximum is recorded at 7.00 p.m. as 17.13. As average hourly consumption was 13.97, the ratio of maximum to average hourly consumption was $\frac{17.13}{13.97} = 1.23$.

Table - 7 Hourly Variation of Water Consumption.
(Mean Value for three days in Jan. 1971)

Time	$Q(m^3/hr.)$	Time	$Q(m^3/hr.)$
1	10.94	14	15.43
2	10.58	15	14.73
3	10.30	16	14.83
4	10.40	17	15.85
5	10.58	18	16.73
6	11.54	19	17.13
7	12.98	20	16.13
8	15.40	21	14.75
9	16.23	22	13.95
10	16.45	23	11.34
11	16.38	24	10.66
12	16.33	Total	335.39
13	15.75	Average	13.97

4. Conclusion.

Taking into account the above discussion, it may be concluded that the ratio between daily maximum and hourly maximum is given as less than 1.5 as well as the ratio between maximum daily demand and average daily demand.

Paper 3a

Appropriate Technology for Water Supply and Waste Disposal in Developing Countries

A Research Project of the World Bank

There is an increasing number of commitments to provide safe water for people in the developing world, at a cost which might even reach $60 billion. Proper waste disposal could cost up to $200 billion more. Technological options for providing this water range from communal wells in rural villages and neighbourhood standpipes in squatter areas to integrated community systems for water supply and waste disposal. Economically feasible options are fewer because they must satisfy financial, developmental, institutional, public health, social, and environmental constraints. Conventional solutions based upon capital and waste intensive practices in North America and Europe result in spending at least three times as much to properly dispose of water as it costs to provide it. The emphasis has consequently been on supplying water without providing for adequate waste disposal which has led to serious water pollution and public health hazards in many countries.

A two-year study of appropriate technology for water supply and waste disposal is underway at the World Bank in order to analyse:

- the technical and economic feasibility of various options which are available for water supply and waste disposal in developing countries;

- the economic and environmental systems effects of technologies which provide for conservation of water and other resources and for reclamation of wastes; and

- the scope for designing technical improvements of existing intermediate technologies to improve their efficiency or enhance their transferability and acceptance.

Considerable urgency attaches to the project because of decisions now being made by officials of developing countries, lending institutions, development agencies, and by their engineering and economic advisers. These decisions are characteristically made on the basis of short-term financial considerations, but they result in long-term commitments with significant social and economic impacts. Even when long-range planning is attempted, the lack of information on low-cost alternatives to conventional systems of waste disposal frustrates effective decision making.

<u>Objective.</u>

The objective of the research is to identify the appropriate technology for providing the urban poor and rural communities with socially and environmentally acceptable water supply and waste disposal services at a cost they can afford.

Scope.

A total of 26 countries are scheduled for study. Of these, 11 have been selected for detailed field studies. The balance are included to provide specialised information or locations for pilot projects. Collectively, the countries include a variety of stages of development, technologies, cultural and institutional forms, and environmental features.

Planned geographic coverage includes (1) Japan, Taiwan, and Korea; (2) Indonesia, Philippines, Malaysia, Thailand, Bangladesh, India, Pakistan, and China; (3) Afghanistan, Egypt, Yemen, and Tunisia; (4) Botswana, Ghana, Kenya, Nigeria, Tanzania and Zambia; and (5) Colombia, El Salvador, Mexico, Nicaragua, and Peru. Principal investigators and supporting consultants ordinarily are selected from host country specialists.

Technological options to be considered include the following either singly or in combinations:

- water service levels of 10 to 500 litres per capita per day obtained from streams, wells, vendors, community standpipes and/or sanitation services, yard spigots, or high-volume plumbing;

- low-cost options for waste disposal by privies, vaults, composting toilets, aquaprivies or cesspools, septic tanks, removal by cart, vacuum truck, or low-flow sewers;

- traditional, advanced, or exotic waste treatment based on composting, digestion, fermentation, oxidation, or spreading of nightsoil, sewage, agricultural manures, or food wastes; and

- reclamation schemes including biogas, fertilizer, aquaculture, pig-raising, stock and garden watering, and irrigation.

Approach.

Data are to be collected on the various technical, economic, environmental, public health, institutional, and behavioural factors that relate to the choice of the appropriate water supply and waste disposal technology. Economic data being collected include costs of construction and operation; of collection, transportation, treatment, and disposal systems; public health and reclamation benefits; costs and availability of construction materials and labour; foreign exchange requirements; and market distortions due to statutory wage, interest, import duty, subsidy, or exchange rates. Public health information being collected includes morbidity, mortality, health services and education, and anecdotal data. Institutional and behavioural data collection includes anthropological and sociological inquiries into how decisions are made, implemented, and maintained at the local level.

For each technology studies at the community level by the field consultants, a technical evaluation of the system's construction and operation first is carried out with special reference to any problems associated with the performance or community acceptance of the existing system. Using standard cost-benefit techniques (including shadow pricing where appropriate) each technology's economic feasibility then is analysed, and average household costs are computed. Special emphasis is given to the ability and willingness of consumers to pay for the system, their real or perceived improvements in health and living conditions, and any obstacles to adaptation of the technology for other communities.

In both the technical and the economic evaluations, an attempt is made to broaden the scope of analysis to include system linkages between the waste disposal technology and its effect on labour and product markets, as well as more complex relationships with other economic sectors such as agriculture and energy where reclamation through fertilizer or biogas production is practiced.

Early Results.

The first phase of the research involved a detailed bibliographic search for literature relevant to low-cost waste disposal technologies. At the same time, field work was initiated in Japan, Korea, and Taiwan. Findings from these initial efforts include the following:

- A title, abstract, and detailed review of 17,000 potentially relevant publications selected by key word indexing revealed that less than 3 percent are of practical value in developing countries; that conventional engineering wisdom indicating that there are no viable technological alternatives lying between pit privies and sewerage systems is invalid; that much information is available on septic tanks but little on pit privies; and that much information exists on treatment of dilute wastes by oxidation ponds but little on treatment of concentrated wastes (nightsoil, sludge, etc.) by composting or aquaculture.

- Field studies of nightsoil collection and/or disposal confirm the findings of the literature review. Studies were conducted in eleven communities with populations varying from 285 to 1½ million in Japan, Taiwan and Korea. Annual per capita income ranges from about $6,000 in Japan to $700 in Korea. Climate varies from humid subtropical to subhumid temperate. Water service levels vary from 100 to 437 litres per capita per day. The annuitized capital and anuual operating costs per household for storage, collection and disposal of nightsoil ranged from about $15 per year in the villages to $115 per year in a city with a high-technology system where nightsoil is diluted for treatment by conventional activated sludge. Reported costs for a complete sewerage system ranged from about $220 to $300 per household per year. Reclamation practices include household biogas units in Taiwan and Korea, commercial aquaculture in Taiwan, and some use of nightsoil as humus and fertilizer in all three countries. Reuse aspects were reported to be more sensitive to convenience and economic factors such as changes in relative prices of chemical fertilizer or labour costs than to concern over public health or aesthetics.

Cooperation, Coordination and Liaison.

Coordination and liaison of research activities are maintained with ongoing programmes of operating departments of the Bank, the World Health Organization, the United Nations Environment Programme and various national research, development, advisory, or operating agencies. Cooperative bibliographic and field research programmes are underway with the International Development Research Centre (IDRC), Ottawa, and the Ross Institute of Tropical Hygiene, London, Principal investigators for country specific studies include local sanitary engineers, economists, urban planners, and public health workers.

Products of the Research.

An early product of the research will be annotated bibliographic and state-of-the-art reports on appropriate waste disposal technology and health effects prepared by the Bank, IDRC, and the Ross Institute. Final publications will include books, field manuals or guidelines, and instructional materials prepared for decision makers in development agencies, developing countries, consulting engineering organizations and universities. These will aid in both the technical and economic evaluation of alternative water supply and waste disposal projects or urban projects with a water supply component. Conceptual and final designs will be developed for improved mechanical devices; for pilot studies of alternative storage, collection, and transportation systems; for composting and land application systems; and for final disposal systems.

June, 1977.

Paper 3b

Choice of remote control and automation installations appropriate to the social and economic circumstances

Peter Grombach, Switzerland

1. Need for remote control and monitoring

One might think that remote control and automation is only something for rich countries like Japan or the United States and that developing countries must not use it. This is not true. The need for remote control and central monitoring exists everywhere because everywhere the limited water resources have to be used most economically. This alone is reason enough for complete monitoring and sophisticated control. In addition, many countries suffer from a shortage of skilled labour and there again remote control or at least central monitoring can help unskilled labour perform a good job. The limited resources are also the reason for the complexity of modern water supply installations where water transport over long distances and great heights as well as complicated treatment has become necessary in the last decades. Finally local automation is often necessary to guarantee that operation is really performed in such a way as the engineer and the treatment plant manufacturer intend it. So it is to be understood that it really is not enough just to place in each plant a number of attendants and watchmen if the correct operation is not centrally monitored and at least partly automatically controlled.

2. Types of equipment for remote monitoring

The need for central monitoring is common all over the world. The use of best equipment is also common but some properties of the equipment are more important in tropical countries than in Europe or America. This is especially true for the sensors without which no monitoring is possible. They must be simple, reliable and easy to handle. This can only be achieved when parameters are chosen for monitoring that are easy to measure, viz. water level, water pressure, electric tension and electric current. It is astonishing how much can be monitored with only these four parameters because water level automatically also gives water storage, pressure together with pump operating time gives according to the properties of the pump the pumped water quantity and together with tension gives pump efficiency. In many cases operation of treatment processes can be monitored also simply by monitoring pump operation.

Parameters that are acceptable only with appropriate maintenance of the sensors are flow measured by induction or ultrasonic, pH measured by micro tension and water quantity measured by traditional water meters. Also acceptable are sensors for temperature and electrical conductivity if the demand in accuracy is not too high. pH and conductivity give first indications of the so important water quality.

Complicated and unreliable under tropical conditions are all Venturi meters and all level gauges operated by floating buoys. The same goes for elaborate turbidity meters and all equipment using chemical reactions. On the other hand, conductivity can easily be gauged to special qualities such as contents of free chlorine or other oxidating materials.

It is emphasized that it is not so much important to choose the right make of a certain instrument than to chose the right parameter that can easily be monitored.

3. Remote control

Remote control is important especially when a water works possesses a great number of small water resources such as deep wells or has to pump water to different heights in hill country. Again we have to choose the right equipment that can easily be remote controlled and avoid all complicated equipment where remote control is difficult. Most reliable is the remote control of pumps up to about 1'000 kW and down to smallest aggregats such as dosing pumps. These machines can easily be switched on and off by standard electrical equipment specially constructed for operation in hot countries. As the operation of these switches is very reliable, so is remote control of them.

Less reliable is the operation by remote control of valves even if they are electrically or hydraulically operated. If possible, remote control of valves should be avoided and replaced by control of pump type machines. If this is not possible, extended maintenance of the valve operating engines is necessary.

Completely unreliable are all magnetic valves, even though the manufacturers deny it. Magnetic valves can only be used for hydraulic oil but never for water or watery solutions. Consequently complicated treatment operations such as filter backwash, operation of settling equipment, ozon treatment or production of chemical solutions should not be remote controlled in detail. For all these operations, remote monitoring combined with local hand operation or local automation is appropriate.

4. Advantages of automation

The main advantage of automation is the continuity of operation which means that the performance is identical day after day and also in accordance with the rules of the engineer. Automatic backwash of filters for instance, means that the periods for air scour, water flush and sludge evacuation is identical and optimal in each backwash and does not depend from the individuality of the operator. The second advantage of automation is reliability and it is unfortunately true that correct automatic equipment is more reliable than even the most conscientious operator who can be ill or indisposed without knowing it. Another very important point in favour of automation is the possibility to avoid shift work, especially at night. Since regular work at night is noxious to health this advantage of automation is to be regarded as a social advantage. Last but not least the automation enables the manager to economize energy and often water as well, both of which are much more important than the small possibilities of economizing labour.

Most suitable for automation are complicated but always identical processes in water treatment such as filter backwash, production and introduction of ozon, handling of chemicals, change of filter materials and the starting of big pumping engines of more than 1'000 kW.

Automation is not appropriate to all processes where visual control is needed such as flocculation settling tank operation or the guard of water work plants against intrusion of unauthorized persons.

5. Appropriate equipment for automatic control

For automatic control virtually the same equipment is appropriate as for remote control. The difference lies only in the number of control mechanisms which can be much bigger with local automation than with remote control. So automation is suitable for the control of pumps of all sizes and of electrically driven valves. Automation is especially suitable for the operated control of complete treatment processes as long as the treatment plant is correctly planned so that one and only one status of operation corresponds to every condition of operation. This means that for instance to each raw water pump one chemical dosing pump is connected, one ozon equipment and one clear water pump. When a second raw water pump is put into operation, then again a second dosing pump, a second ozon installation and a second clear water pump should go into operation so that the whole treatment plant is devided in a certain number of fixed blocks.

As it was said for remote control, automatic control has to avoid the use of magnetic valves for water and in addition should if ever possible avoid regulation processes such as engines running at variable speed or dosing pumps with variable stroke.

The control mechanisms for automatic operation should always be equipped with fixed wired electronic plates that can be changed easily by stand-by plates in case of failure without necessity of elaborate search for the cause of the failure. The necessary stand-by equipment must be purchased together with the automatic equipment itself. Some manufacturers are ready to make even a contract for re-delivery of the necessary exchange parts for a period of up to five years. It is important that only fixed wired plates of the electronic type are used and that in situ wired installations with heavy maintenance problems are avoided. The advantage of the fixed wired plates is also the possibility to place them in sealed boxes of stainless steel or reinforced plastic to avoid damages due to the hot climate.

6. Ways and means to introduce remote control and automation

The best moment to introduce remote control and automation is the time of construction of new treatment plants. But it is also possible to introduce automatic control in existing or even old plants provided that the necessary changes of operation are being made. Changes are necessary wherever operation differs from the simple block operation with fixed performance as described above.

To start the introduction of remote or automatic control, it is necessary to define exactly the task that the new equipment should fulfill. This is best done by describing the shortcomings of the existing system, for instance difference of operation or unsufficient reliability. It is also advisable to set from the beginning a cost limit so that the planning engineer knows from the start what of the great variety of possible controls of the operation lies in the limits. The cost limit should be calculated according to a cost-benefit analysis and not set just at random.

When the general idea of remote or automatic control is clear, a detailled scheme of the water supply and a scheme of the intended control installations is to be set up. From the very beginning it is important to try and get radio frequencies for the connection between the dispatching center and the different water supply plants. As the possibilities of frequencies are limited, certainty about the frequency to be used is necessary before detailled planning of the connections is possible. Finally it is necessary to set up an exact list of the tasks that the new equipment has to fulfill and to describe in detail the operating programs.

Having acquired these data, it is possible to make a call for tender. The tenders should give also detailled information about flexibility of the system, free capacity in addition to the capacity necessary for the detailled task description and indication about stand-by equipment where this is felt necessary. In evaluating the different tenders, the water works engineer should realize that simple systems are always better than sophisticated equipment, that one single apparatus should not have too many different tasks (one programming unit should not control as different equipment as transmitters, pumps and valves) and that exact documents and detailled operating instructions are as important as good hardware. The quality of the sensors is decisive for the quality of the whole control system and all sensors should at least be isolated according to IP66 or placed in field boxes of waterproof material. It is important to examine the tenders carefully for equipments that can be omitted by slight changes in the water works operation. Small parts of the task description often cause high unneccessary costs that can economized by slight changes of the tasks. Last but not least it is always dangerous to choose new unproven equipment and it is much better to purchase equipment that could be inspected in full operation at some other site.

Implementation of the new control equipment is the last step to the new operation. If no free frequency for the connecting radio links could be reserved, then transmission cables have to be laid. This is a tedious and time-consuming job that must be begun immediately after acceptance of the project. In the same time instruction of the personal about the new operating methods has to begin, so that with the end of the mounting of the new equipment the personal is thoroughly aware of its new duties. After starting the new devices, the engineer must realize that modern electronic equipment tends to early breakdowns of a certain percentage of the transistors. These early breakdowns will cease after a few months and have no meaning to the reliability of the whole system. The operation should start with monitoring as this is less dangerous than remote or automatic control. With central monitoring first experiencies can be gathered so that the difficult step into remote control will be easier. If there is an existing control system, such as hand operation or a local control center, then the old and new systems should work for some time in parallel until the new system has proved its advantages and its reliability.

7. Conclusion

No foundamental difference lies between traditional hand control and remote or automatic control but when you introduce automatic control, start with monitoring, choose the equipment appropriate to the climate, limit your demands to the possible, be sure that the manufacturer of the control equipment is locally represented and do not forget maintenance in all the years to come.

Paper 3c

Advances in the Treatment of Surface Waters Used for Drinking Purposes

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SUMMARY

Major recent advances concerning treatment methods involve the use of oxidants (chlorine, chlorine dioxide, ozone), adsorbants (granular or powdered activated carbon), natural and synthetic aids plus nitrification processes.

Several other technological developments dealing with raw water analysis, clarification, filtration and disinfection are also discussed.

INTRODUCTION

Two main factors are responsible for recent advances in surface water treatments:

- research aimed at producing better quality treated water in compliance with more severe standards
- more accurate determination of impurities present in water in the trace state thanks to the development of such modern measurement methods as gas chromatography, atomic absorption, mass spectrography, etc.

We propose examination of several new developments from the double viewpoint of process application and technology and the definition of treatment possibilities as a function of the type of water to be treated.

A. ADVANCES IN TREATMENT METHODS

Major advances concern:

- the action of oxidants such as chlorine, chlorine dioxide and ozone
- the action of adsorbants, and particularly activated carbon
- the use of anionic and cationic aids
- the use of nitrification processes for ammonia removal

It is evidently impossible to go into detail for each of these points and to examine their incidence on various types of surface waters since most treatment processes involve interactions which permit a great number of combinations. We shall thus limit discussion to major characteristics.

I. ACTION OF OXIDANTS

1. Chlorine

Today, chlorine remains the basic product for water prechlorination and disinfection, but newly introduced measurement procedures reveal that chlorine reacts with certain organic compounds, and in particular with humic matter and organic compounds resulting from vegetal decomposition, to form, under certain conditions, compounds known as haloforms which can be dangerous to health at high concentrations. The most dangerous of these products from a health point of view are the trihalomethanes, the most common form of which is chloroform.

a. Raw water containing few precursors, i.e. organic compounds susceptible to give rise to haloforms in the presence of chlorine: Such water can be perfectly treated by prechlorination, the benefits of which are widely recognized, especially for warm and colored waters rich in plancton. Prechlorination must not be condemned.

b. Raw water rich in precursors: Since the addition of chlorine can cause haloform formation (cf curves 1) under certain conditions, it is advisable to eliminate as much of the organic matter, and thus the precursors, as possible prior to chlorine introduction. The following products are effective for both haloform destruction and the limitation of formation: chlorine dioxide, ozone, and granular or powdered activated carbon.

c. Water rich in ammonia and organic matter: Prechlorination remains a feasible solution without involving the formation of a significant amount of chloroform provided that:

- either the chlorine dose is limited such that it corresponds to the formation of monochloramines only, i.e. the first rising branch of the breakpoint curve

- or the ammonia is first removed by a process other than chlorination

2. Chlorine dioxide (ClO_2)

Advantages

In contrast to chlorine, chlorine dioxide does not lead to haloform formation provided that it is correctly prepared, i.e. with maximum efficiency as concerns ClO_2 formation and little excess chlorine.

Moreover, chlorine dioxide does not give rise to chlorophenols, which can render a water unfit for drinking, and oxidizes any phenols present. It also destroys chlorophenols when used for final disinfection following prechlorination of a raw water containing phenols with chlorine.

Disadvantages

- ClO_2 has no effect on ammonia
- ClO_2 reacts with organic matter in water; the risks of reduction to the ionic form ClO_2^- require attention as this ion is suspected of being dangerous to health
- When used for prechlorination, ClO_2 can form suspect, and thus undesirable, compounds.

Examination of the advantages and disadvantages of ClO_2 points out the necessity of avoiding this product for preoxidation and of limiting application to disinfection at the end of the treatment scheme.

3. Ozone and activated carbon

We shall limit discussion to the latest developments in application of these products:

3.1. Improvement of organoleptic qualities and disinfection

3.1.1. Taste improvement

Prechlorination can aggravate the "fishy" and "muddy" tastes of certain dam reservoir waters. Such tastes can be eliminated by the use of ozone alone or by using a combination of ozone and powdered activated carbon; this last product must be introduced during the clarification stage to permit a sufficient contact period and concentration.

In certain variable level dam reservoirs or rivers, the release of geosmine by actinomycetes, a type of fungus, causes a taste which even normal doses of ozone and powdered activated carbon cannot totally eliminate. Treatment requires either very high powdered activated carbon doses or final filtration on granular activated carbon.

3.1.2. Disinfection using ozone

Ozone is well known for its disinfectant properties vis-à-vis both pathogenic bacteria and viruses present in surface waters even at low doses and with short contact periods, whereas high doses and contact times of several hours to an entire day would be necessary to obtain the same virucidal effect using chlorine.

The ozone dose introduced in the first compartment of the disinfection contact chamber (Fig. 2) depends primarily on the water's temperature, pH and composition plus any prior treatment.

- With a correctly treated water containing a normal amount of organic matter, ozonization employed for disinfection gives rise primarily to direct reactions; no significant difference is observed in the ozone consumption whether pH correction takes place before or after ozonization.

- In contrast, waters rich in organic matter, especially of a humic or fulvic nature, involve not only direct reactions but also indirect reactions whose importance increases in direct proportion to the pH.

Graph n° 3 shows the difference in ozone reactivity as a function of the pH of a water with a very high humic matter content. At pH values below 6.3, an ozone dose of 4 ppm is required in the first contact chamber compartment to obtain a 0.3 ppm residual; the injection of 6 ppm at pH 8 gives no residual at all.

3.2. Effect of ozone on the biodegradability of dissolved substances

Recent studies have shown that ozone can transform certain non-biodegradable dissolved substances into biodegradable substances. Ozone can thus be injected prior to filtration, which serves as a support for bacterial life.

While granular activated carbon is the optimum support for such filtration due to its combined action as an organic matter adsorbant, all other porous supports permit the same bacterial development. The primordial condition for such development is elimination of the excess residual ozone prior to filtration.

In any case, we cannot overemphasize the necessity of filtration after ozonization when previous treatment has not retained a sufficient amount of the organic matter, plancton, detergents and other non-biodegradable or oxidizable substances which give rise to precipitates or bacterial developments.

If ozone is to be used for final disinfection treatments, the previous treatment must be sufficiently complete and effective such that ozonization does not entrain the formation of either precipitates or other developments.

3.3. Pretreatment of a polluted surface water by ozonization

As an example we have chosen the Seine river upstream from Paris. Graph n° 4 reveals the influence of a low ozone dose in pretreatment prior to clarification in a PULSATOR sludge blanket clarifier employing ferric chloride as a coagulant:

- introduction of 0.1 g/m3 of ozone significantly improves both the clarified water's turbidity and organic matter elimination measured by ultra-violet
- above 0.2 g/m3, there is no longer any influence on the clarified water's turbidity and improvement of organic matter elimination drops significantly

Use of a low ozone dose for pretreatment improves the clarified water's quality while palliating the defects of more or less precise coagulant dose adjustment with respect to the optimum dose.

3.4. Ozone vis-à-vis haloforms and other organic compounds

In addition to not producing haloforms itself, ozone can reduce the chloroform content of a water; part of its action is due to stripping caused by aeration after injection of a flow of gas; ozone's chemical action is responsible for other effects.

However, use of ozone for highly polluted waters, especially at low doses, can lead to the formation of compounds which must be destroyed either by more thorough oxidation (post-ozonization for example) or by adsorption on activated carbon, or by a combination of these two processes.

Polycyclic aromatics and polychlorinated biphenyls are reduced provided that prechlorination and ozonization are associated; in contrast, chlorination alone or ozonization alone tends to increase the concentration of such compounds.

3.5. Chlorination after ozonization

Ozone creates a chlorine demand in a water which does not have one prior to ozonization. Moreover, ozone remanence doses not exceed 30 minutes at the doses normally employed. Thus, final chlorination at a low dose is necessary as a complement to ozonization. Use can be made of chlorine, hypochlorite or chlorine dioxide. However, in the presence of residual ozone, chlorine dioxide is transformed to a large degree into chlorate; use of ClO_2 following ozonization therefore requires prior elimination of the residual ozone.

3.6. Ozone installations

Ozolab was specially designed and perfected to satisfy the most exacting laboratory requirements as well as to serve as semi-industrial test units.

Connection to an air supply and a source of cooling water under pressure suffices for production of up to 8 to 16 g/hr of ozone from air or 13 to 26 g/hr of ozone from oxygen.

- Monobloc OZONAZUR type A ozonizers consist of a standard cabinet housing all of the equipment required for air drying, ozone production, and the monitoring and protection of the unit. Depending on the number of tubes utilized, they can produce up to 150 g/hr of ozone from pressurized air supplied by a compressed air network or auxiliary unit. (Fig. 6)

- Monobloc type MP ozonizers are similar, but the number of tubular dielectrics varies. They can produce up to 2500 g/hr of ozone from air supplied by a compressor or an auxiliary network. (Fig. 7)

- Large ozone production installations are equipped with separate units, plus the necessary backup material, ensuring air compression, air drying, ozone production, the supply and regulation of electric current, electric monitoring and ozone injection.

These tubular, water-cooled dielectrics are designed to accept the input of air, oxygen-enriched air or pure oxygen, and operate on a normal frequency of 50 or 60 Hz or at a medium frequency created by an appropriate static converter.

II. USE OF NATURAL AND SYNTHETIC AIDS

1. Efficiency

Aids have numerous roles in surface water treatment:

- Aids were first used in clarification to improve flocculation, floc retention and the quality of the clarified water; this utilization is especially indispensable for the treatment of cold waters coagulated with aluminum sulfate which are noted for being hard to flocculate at low temperatures. Aids are also useful for the treatment of polluted waters, regardless of their temperature, to improve organic matter and plancton removal.

- Aids also improve the efficiency of coagulation on filters without clarification by causing substantial reduction of the turbidity, color, organic matter, plancton, etc. and especially by preventing premature filter breakthrough.

- Recently introduced cationic aids can improve coagulation when employed either alone or in association with a coagulant such as aluminum sulfate or ferric chloride. They often permit a significant savings on coagulant.

- Aids are of particular interest for sludge treatment.

2. Type

Both natural and synthetic products are available:

- Alginate is not always very effective and the doses required are often costly.

- Activated silica is much less expensive and generally effective with all types of water. However, its activation must be closely controlled, otherwise action is considerably reduced.

- Not all synthetic polymers can be used for drinking water. Research conducted in various countries has shown that they are perfectly adapted to drinking water treatments provided their monomer content is less than 0.5 % by weight as this substance is likely to dissolve.

  The interest of such polymers resides in much easier preparation and constant efficiency without the need for any particular controls. They greatly facilitate operation and their cost is perfectly acceptable when used at normal doses of 0.05 to 0.2 ppm (powder-form products).

III. UTILIZATION OF NITRIFICATION PROCESSES FOR AMMONIA REMOVAL

Surface waters are increasingly richer in ammonia: while no limit has been set for this substance in international standards, it creates problems during treatment and water distribution.

This is why the Official Gazette of the European Community presently sets strict limits for ammonia contents in drinking water:

- optimum content or guide level: less than 0.05 mg/l of NH_4
- maximum admissible concentration: 0.5 mg/l

For low ammonia contents, chlorine can be used at the breakpoint if the water has a low organic matter content to avoid the formation of haloforms. However, the cost of chlorination rapidly becomes prohibitive as soon as the NH_4 content rises since 8 to 10 g of chlorine must be used per gram of ammonia nitrogen.

For ammonia contents up to 6 to 8 g/m3, we have designed and developed a process for biological nitrification on an immersed filter with continuous aeration. (Fig. 8)

Provided that engineering is adapted to the ammonia content and the water's pH, this process offers good nitrification efficiencies of 80 to 85%.

B. TECHNOLOGICAL ADVANCES

I. AUTOMATIC ANALYSIS UNIT

This unit monitors the quality of a raw surface water prior to its admission to a drinking water treatment plant by measuring at least 5 factors: resistivity, pH, temperature, dissolved oxygen, turbidity.

This unit has an autonomy of two to three weeks. The measurement ranges and accuracies are listed in the table below: (fig. 9)

Parameter	Units	Measurement range	Accuracy
Conductivity	S/cm	0 - 1000	± 20
pH	pH units	6 - 9	± 0.1
Dissolved O_2	saturation %	0 - 150	± 2
Temperature	° C	0 - 40	± 0.5
Turbidity	JTU	0 - 100	± 5

Use of this unit for a surface water, upstream from a treatment plant, allows the detection of accidental pollution with better accuracy and security than apparatus based on the use of fish for monitoring purposes, such as the ICHTYO-TEST. (Fig. 10)

II. AUTOMATIC UNIT FOR REGULATION OF THE PRECHLORINATION CHLORINE DOSE JUST OVER THE BREAKPOINT

Since addition of too much chlorine in excess of the breakpoint leads to unnecessary expenses and risks increasing the concentration of harmful organic compounds, the amount of chlorine used in prechlorination must be controlled to prevent the formation of excessive free chlorine.

We therefore developed a photocolorimeter (Fig. 11) which automatically monitors the free chlorine content 6 times per hour using a specific reagent.

To allow automatic control of prechlorination at a plant, a predefined free chlorine content is set, for example 0.3 or 0.5 ppm: a regulator adjusts the chlorine dose injected as a function of the result indicated by the photocolorimeter every ten minutes. This monitoring frequency has been proved amply sufficient during operation.

III. IN SITU SODIUM HYPOCHLORITE PRODUCTION (Fig. 12)

All of the problems arising from chlorine procurement, storage and protection against leaks can be avoided by in situ disinfectant production. A solution of sodium hypochlorite can be obtained on the site by electrolysis of a sodium chloride solution or seawater.

Our SEACLOR electrolyzers (NORA licence) guarantee an electricity consumption of 4.5 kW/kg of active chlorine equivalent using seawater or brine (approximately 5 to 7 kg of NaCl are required for 1 kg of chlorine equivalent).

These standard units cover a range of 0.5 to 150 kg/hr and allow obtention of sodium hypochlorite solutions at a satisfactory concentration of 2.5 g/l of active chlorine from seawater and 5 g/l from brine. Such units can operate on an entirely automatic basis as a function of the flow and/or the residual chlorine.

IV. IMPROVEMENTS IN PULSATOR CLARIFIERS

The PULSATOR, our concentrated sludge blanket clarifier/flocculator offering optimum efficiency for surface water treatment, both for clarification and organic matter and plancton elimination, has undergone several modifications.

a. Automatic extractions controlled by turbidity meters: We have developed a system for automatic control of sludge extractions as a function of the amount of sludge produced: this limits water losses due to extractions to a minimum while allowing sludge concentrations as high as possible.

Each row of concentrators has the form of a general channel with small hoppers at the bottom. (cf diagram n° 13)

A small sampling pipe draws off sludge from a point below the top of the concentrator channel and continuously feeds a turbidity meter specially designed for turbid liquids by gravity. This instrument causes the extraction valves to open for an adjustable predetermined duration when the sludge concentration at the sampling point is higher than a value set previously as a function of the sludge's nature.

The concentrator channel thus almost always functions completely full: this permits an average sludge concentration double that possible without such an automatic analyzer.

This system considerably reduces water losses due to sludge extraction and adapts extractions to variations in the raw water quality and the flow treated without necessitating staff intervention.

b. PULSATOR with modules above the sludge blanket: The maximum rise rate in PULSATORS can be increased by an average of 50% by the installation of modules above the sludge blanket (cf diagram n° 14).

The PULSATOR is the ideal unit for obtention of maximum efficiency from such modules:

- since rise rates are uniform at all points over the PULSATOR surface, all module elements are fed equally
- superposition of the flocculation zone constituted by the sludge blanket and the module zone allows passage from the first zone to the second one without breakup of the floc entrained
- most of the sludge is extracted by the concentrators before part of the sludge rises into the modules: this prevents sludge entrainment by the upper part of the modules.

Curve n° 15 shows the performances obtained with a warm water such as that of the Rio de la Plata (Argentina). Addition of modules with a hydraulic diameter of 80 mm in a standard PULSATOR which operated at 3.65 m/hr over the total surface (i.e. 4.45 m/hr over the sludge blanket) increased the flow by 50% without the use of an aid, and by 90 to 125% when a synthetic polyelectrolyte was employed. The corresponding rates over the total surface rose to 5.3 m/hr without an aid and 7.8 m/hr with an aid.

Similar results are obtained with cold waters. Curve n° 16 shows the possibilities of a PULSATOR with modules above the sludge blanket at a plant in Canada.

It can be concluded that use of a PULSATOR with modules above the sludge blanket permits the obtention of clarified water with a maximum turbidity of 3 JTU under the following conditions:

- with warm waters ($T \geq 18°$ C) provided a good aid is used and a rate of 6.50 - 7.75 m/hr over the total surface is adopted

- with <u>cold waters</u> if a good aid is used and a rate of 4.5 to 5 m/hr over the total surface is employed

These performances point out the advantage of using module type PULSATORS when the goal is maximum capacity in a small space and when attempts must be made to reduce the cost of civil engineering works.

V. SUPERPULSATOR

Increase of the rise rate in a PULSATOR equipped with modules above the sludge blanket causes a significant drop in the concentration of sludge in the blanket. For certain polluted waters, this can mean reduced efficiency vis-à-vis organic matter and micropollutant removal.

To obtain the same concentration of sludge as in a standard PULSATOR while operating at a high settling rate, we have patented a system in which plates are added in the sludge blanket itself: this led to the SUPERPULSATOR (fig. 17).

Spaced relatively far apart (0.33 m between centers), these plates are installed such that a portion is situated in the sludge blanket while the remainder projects above the blanket; angle deflectors are installed on the upper surface of the canals created by these plates (fig. n° 18).

These deflectors are designed to replace in suspension the sludge which tends to slide down along the lower plate of each "canal". Instead of two separate types of flow (sludge and water) between the plates, there is a practically homogeneous sludge suspension.

Performances

- Table n° 19 reveals that, following the addition of plates with their angle deflectors, the sludge percentage in the sludge blanket of a SUPERPULSATOR operated at a rate of 8 m/hr is about the same as that in a PULSATOR operated at 4 m/hr over the sludge blanket. The SUPERPULSATOR thus has the same efficiency as a standard PULSATOR as concerns pollution retention.

Type of PULSATOR and rise rate over the sludge blanket	Suspended solids content in the clarified water	Sludge % (by volume) in the sludge blanket after 10 min. of settling
Standard PULSATOR - 4 m/hr	1.5 to 3 mg/l	36 %
SUPERPULSATOR - 4 m/hr	0.8 to 1 mg/l	52 %
SUPERPULSATOR - 8 m/hr	1.3 mg/l	31 %

- The rise rates admissible over the sludge blanket of a SUPER-PULSATOR are approximately double those for a standard PULSATOR.

- Figures n° 20 and 21 compare the performances of a SUPERPULSATOR and a PULSATOR with modules above the sludge blanket for cold water (temperature 6° C) and warm water (temperature 18° C) as a function of the clarified water quality.

  SUPERPULSATOR performances concerning the settling rate are much better than those of a module-equipped PULSATOR for the same quality clarified water.

- The additional advantage of the SUPERPULSATOR is the wide space between the plates which eliminates all risks of clogging with raw waters containing large amounts of suspended solids or plancton.

  The SUPERPULSATOR can be equipped with the same system for automatic extraction control by a turbidity meter as a standard PULSATOR.

  All of the SUPERPULSATOR's characteristics make this unit a high performance clarifier as concerns both the settling rate and the clarified water quality obtained.

VI. AQUAZUR V FILTER

a. AQUAZUR filter characteristics

Like the model T filter equipping the SCUDAI plant, the model V filter employed at the CHOA CHU KANG installation is an AQUAZUR filter and is thus based on the following principles:

- use of a single bed of sand whose effective size is generally between 0.75 and 1.35 mm depending on the treatments applied
- filtering bed consisting of sand with a homogeneous grain size throughout the bed which remains homogeneous after washing
- filtering bed backwashed simultaneously by water and air: this is the only process which maintains the sand homogeneous throughout the entire bed and prevents mud ball formation
- equal distribution of the water to be filtered among all the filters at the water inlet to the units
- regulation of the filtered water flow as a function of the water level in the filter

b. The reputation of model T filters (fig. 22) is backed up by the 300,000 m2 of such units in service throughout the world. These filters are characterized by a shallow water depth (0.50 m) above the sand, a geometric fall limited to approximately 2.00 m and a filtration rate generally limited to between 5 and 7.50 m/hr.

c. The AQUAZUR V filter (fig. 23) was developed to eliminate the problem of air accumulation within the filtering bed, to permit an increase in the amount of matter which can be retained and to allow use of higher filtration rates (commonly between 7 and 15 m/hr and in certain cases 20 to 30 m/hr).

These filters are characterized by a great depth of water above the filtering bed (generally 1.20 m), a deep sand bed (0.80 to 1.50 m) and a system for surface crosswashing with clarified water which accelerates the evacuation of impurities.

d. Improved filtered water regulation

AQUAZUR V filters can be equipped with either a regulating siphon controlled by a partialization box installed in the filter or a RCN type hydroelectric regulator controlling the filtered water butterfly valve (diagram n° 24).

The RCN regulation unit includes a diaphragm type sensor which detects the level to be maintained constant in the filter; no moving mechanical parts are employed. An amplifier built into this sensor sends a signal representing the electrically measured level to the regulation rack. This rack is equipped with a set of highly reliable, removable printed circuit cards as well as all necessary adjustment controls and alarms.

All of the racks at a plant can be installed in a cabinet placed either in the general control room, protected from humidity, or in an air-conditioned room in the filter desk gallery.

In addition to obviating the need for filtered water outlet basins, this technique ensures greater regulation stability and facilitates monitoring and operation of a greater number of filters.

VII. SLUDGE TREATMENT

a. At a plant utilizing a clarifier (diagram n° 25)

The filter waste wash water can be stored in a tank and returned globally, without clarification, to the clarifier inlet at a low flow.

The sludge extracted from the clarifiers is concentrated in a thickener. Following the addition of lime at the inlet of a second thickener, this sludge easily reaches a concentration of 30 g/l; this value permits optimum dewatering efficiencies (60 to 70% moisture content depending on the lime dose) when use is made of a filter press with automatic plate-opening system.

Low capacity installations can employ our PRESSDEG pressure belt filter; a final dose of quicklime produces a stable sludge with a sufficiently low moisture content to permit shoveling.

b. <u>At a plant with only coagulation on filters</u> (diagram n° 26)

The waste wash water from the filters can be collected and clarified in a clarifier. The supernatant can be returned to the inlet of the filters; the sludge can be treated like that extracted from clarifiers.

All of the discharges from a drinking water treatment plant can thus be treated, avoiding any undesirable rejects harmful to the environment.

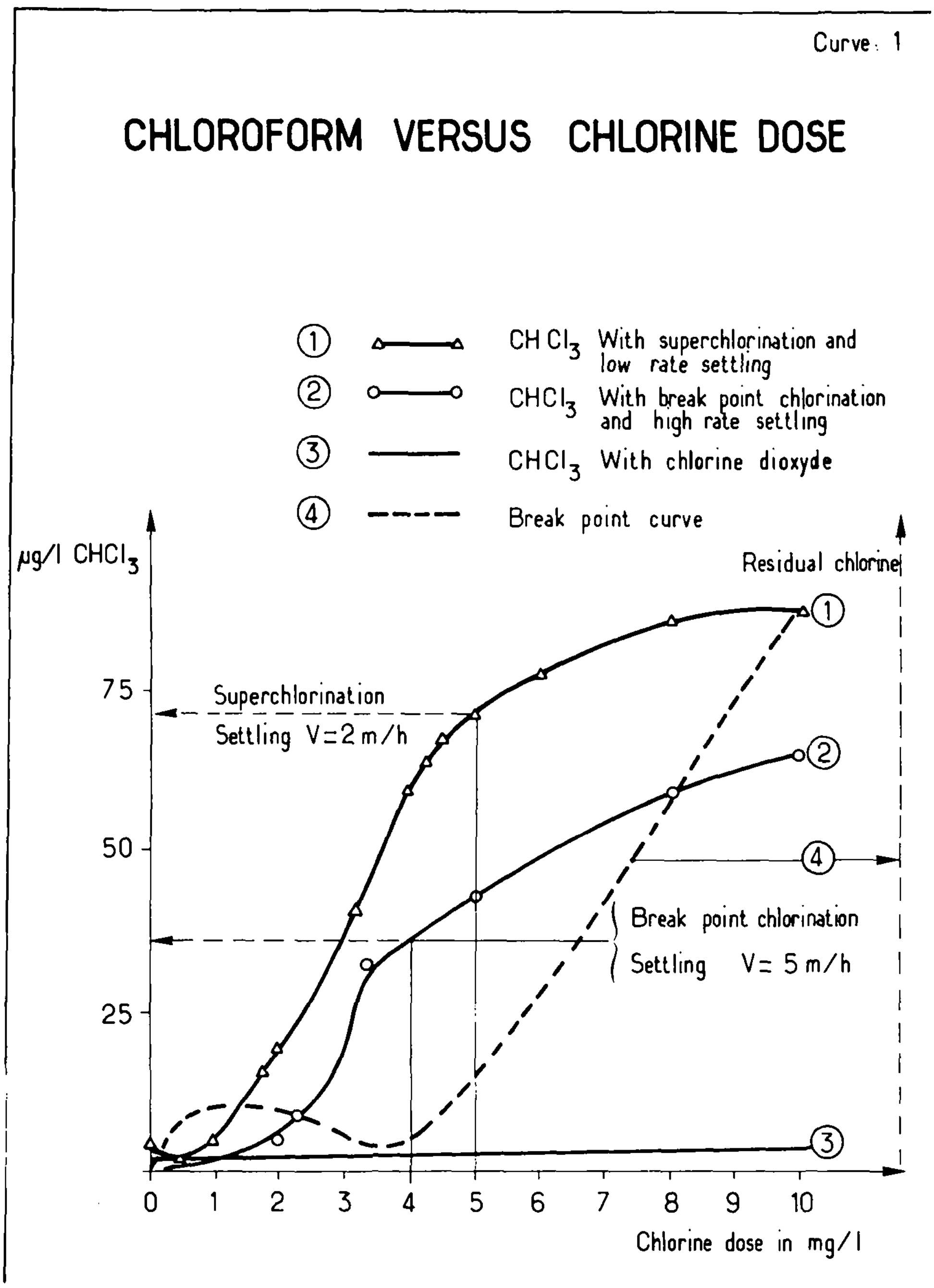
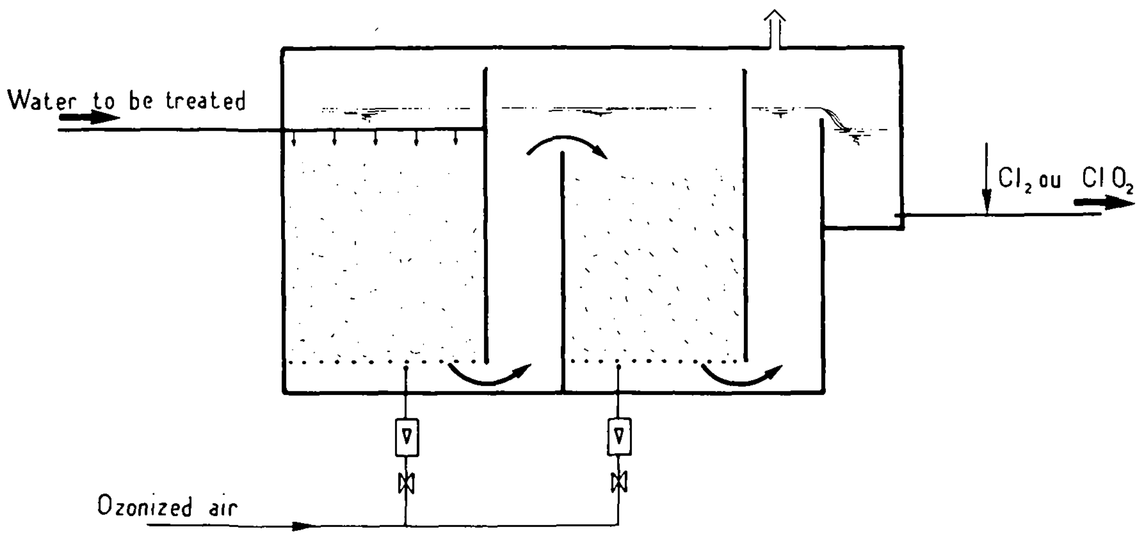

Curve: 1
CHLOROFORM VERSUS CHLORINE DOSE
① CH Cl3 With superchlorination and low rate settling
② CHCl3 With break point chlorination and high rate settling
③ CHCl3 With chlorine dioxyde
④ Break point curve
µg/l CHCl3
Residual chlorine
75
50
25
Superchlorination
Settling V=2 m/h
Break point chlorination
Settling V= 5 m/h
0 1 2 3 4 5 6 7 8 9 10
Chlorine dose in mg/l

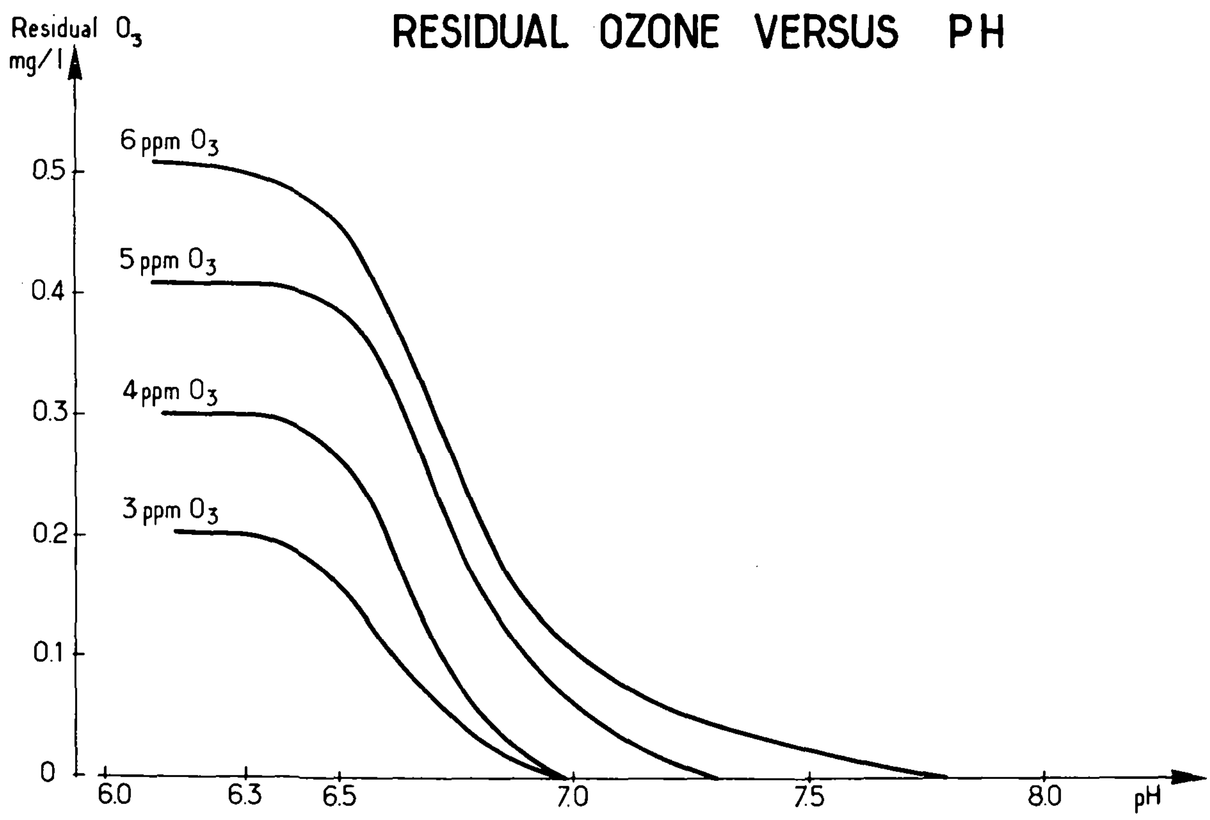
Figure n° 2

OZONIZATION



Curve n° 3

RESIDUAL OZONE VERSUS PH



INFLUENCE OF THE OZONE DOSE ON CLARIFICATION AND ORGANIC MATTER REMOVAL

Curve : 4

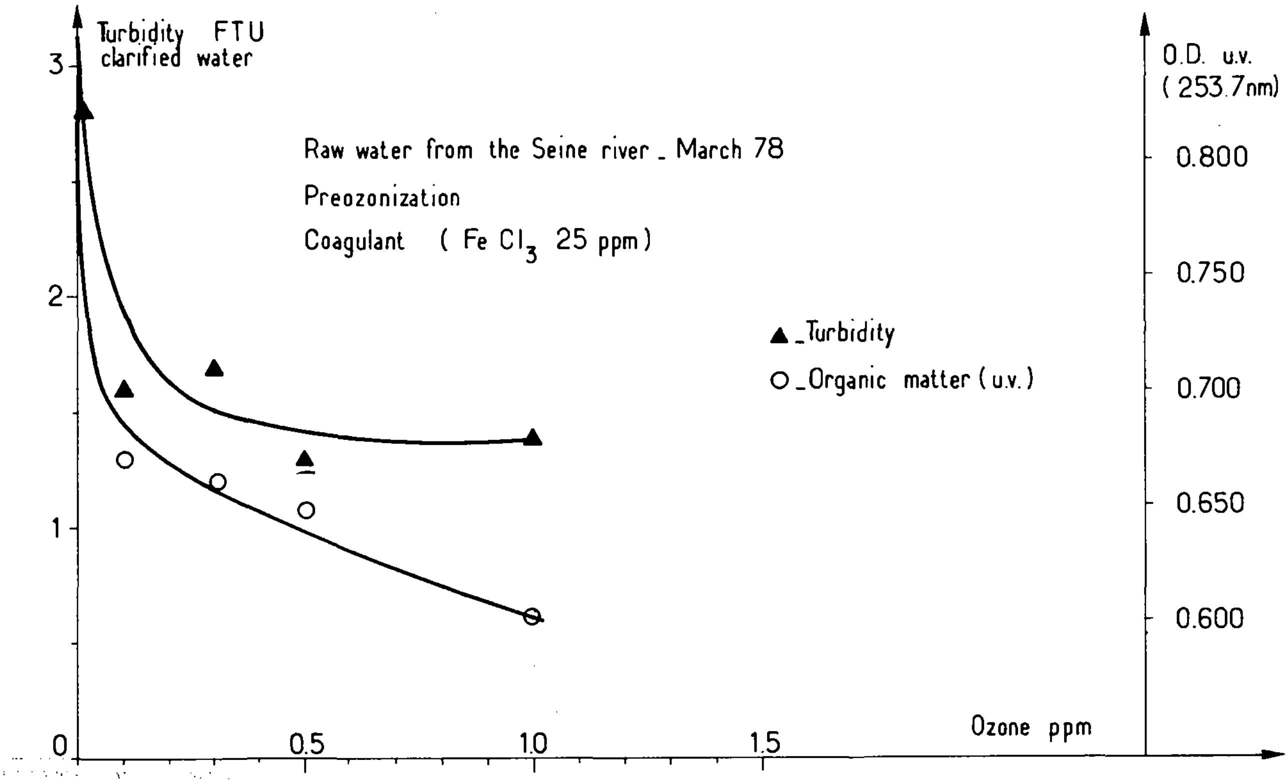
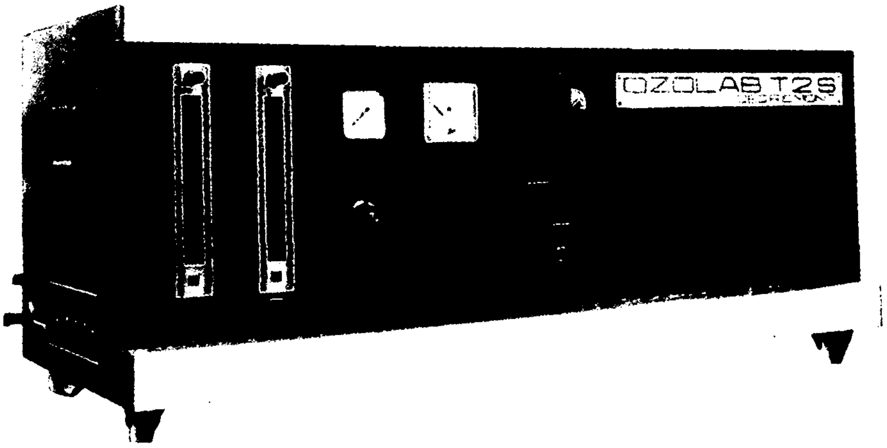
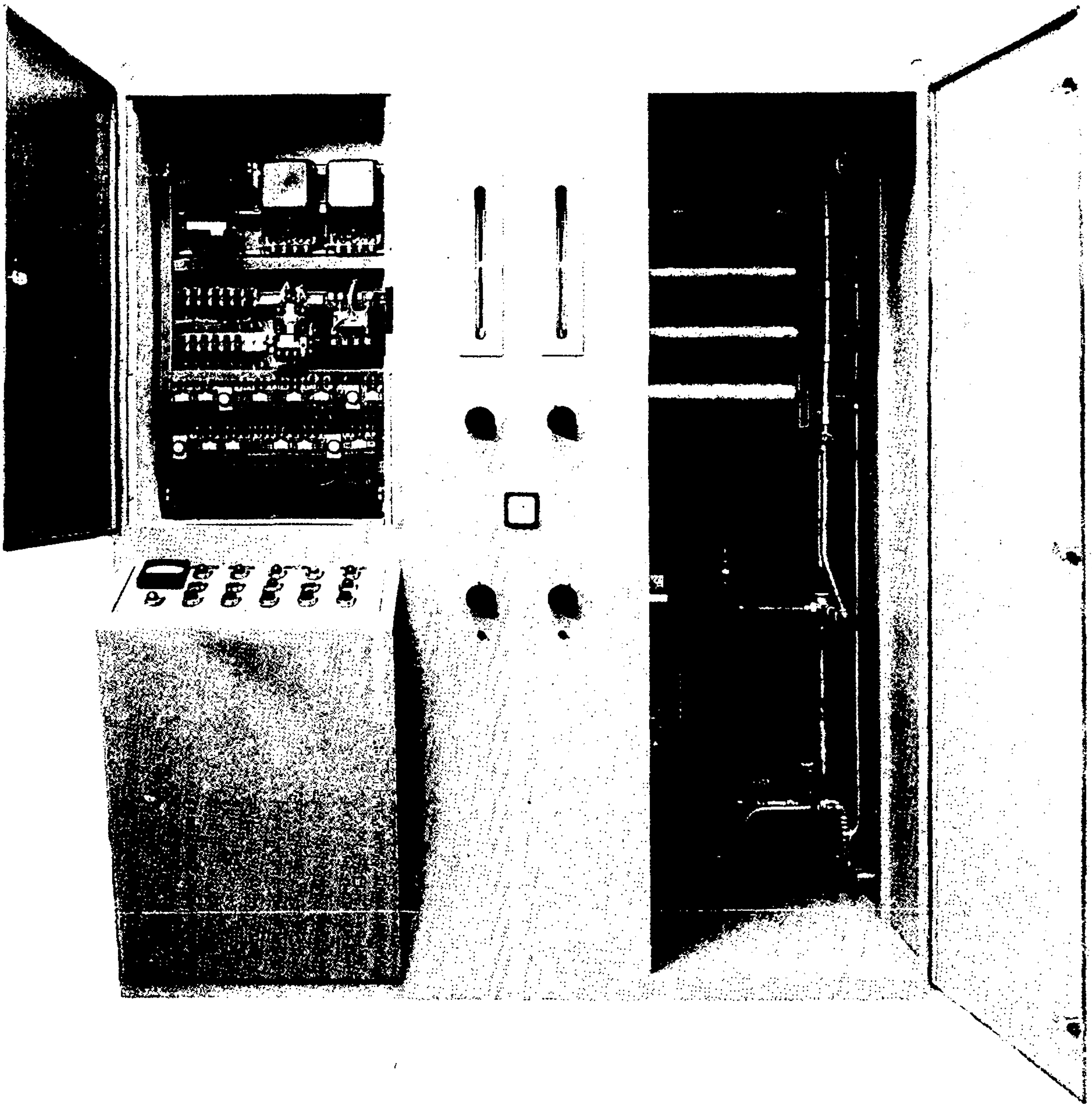


fig. 5

THE OZOLAB

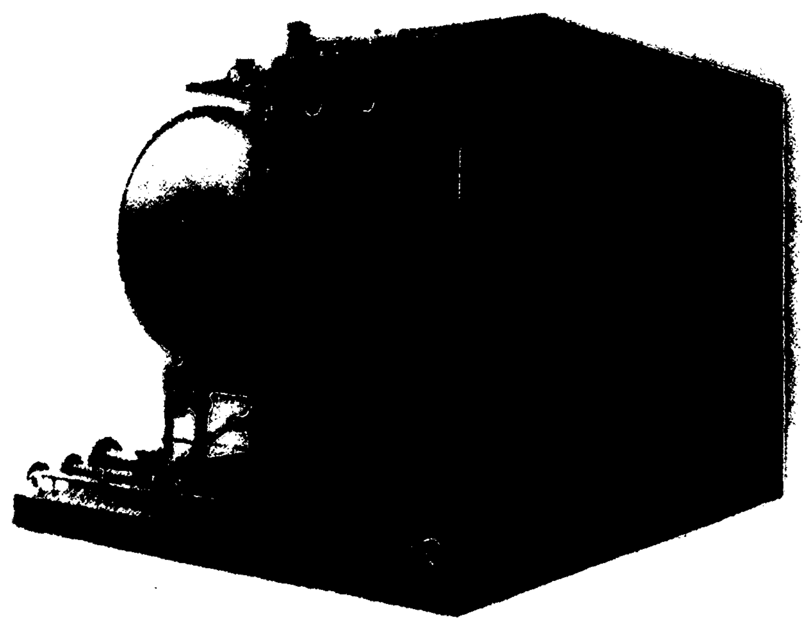




Monobloc ozonizer (4 tubes)

Fig. 7

Monobloc ozonizers ozonazur type



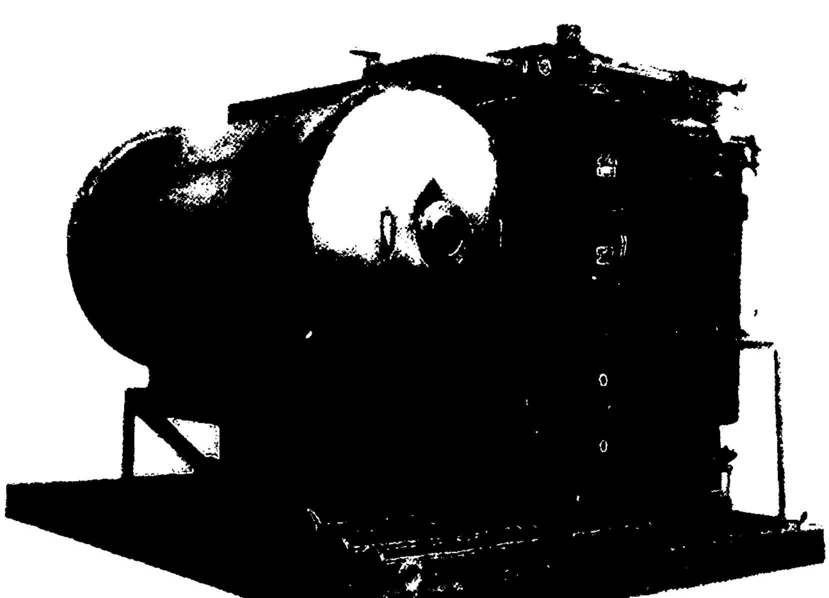


fig. 8

BIOLOGICAL NITRIFICATION

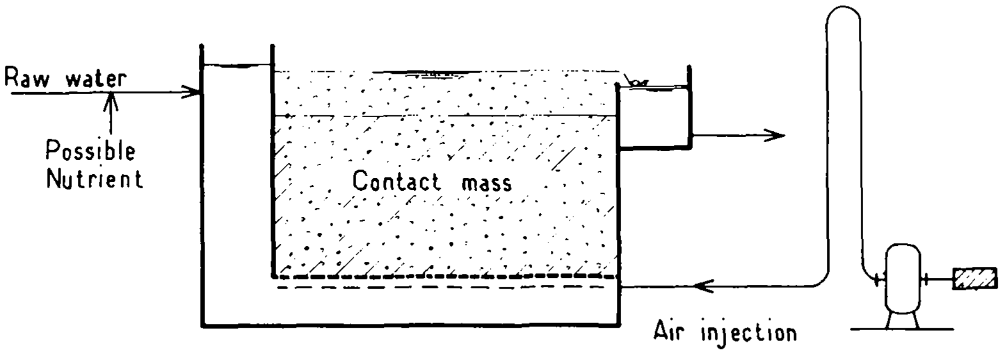


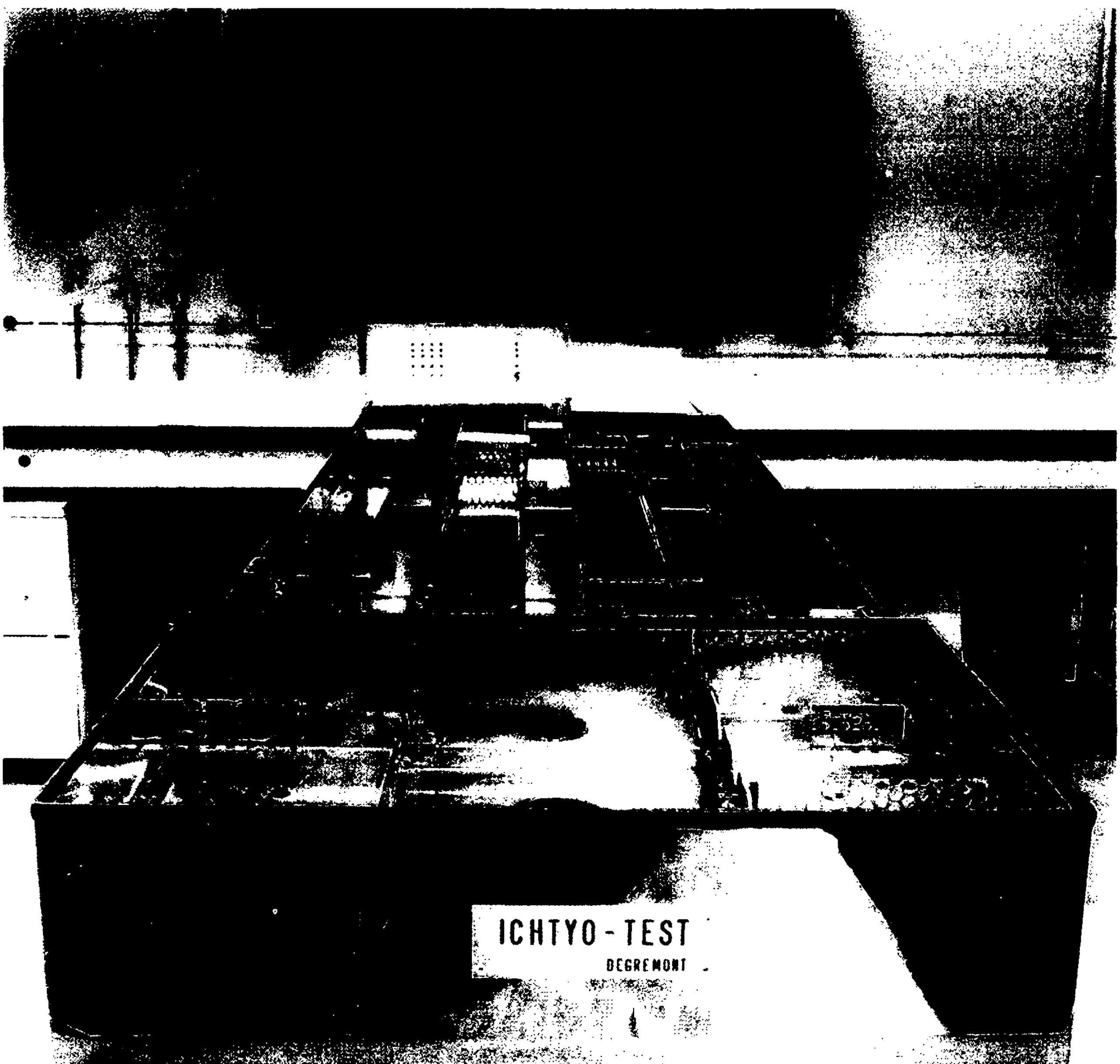
Fig n° 9

AUTOMATIC ANALYSIS UNIT

Range of mesurement and accuracy

Nature	Unit	Range of mesurement	Accuracy
Conductivity	S/cm	0 _ 1000	± 20
pH	Unit _ pH	6 - 9	± 0,1
Dissolved O_2	% of saturation	0 - 150	± 2
Temperature	°C	0 - 40	± 0.5
Turbidity	JTU	0 - 100	± 5

fig. 10



The photocolorimeter

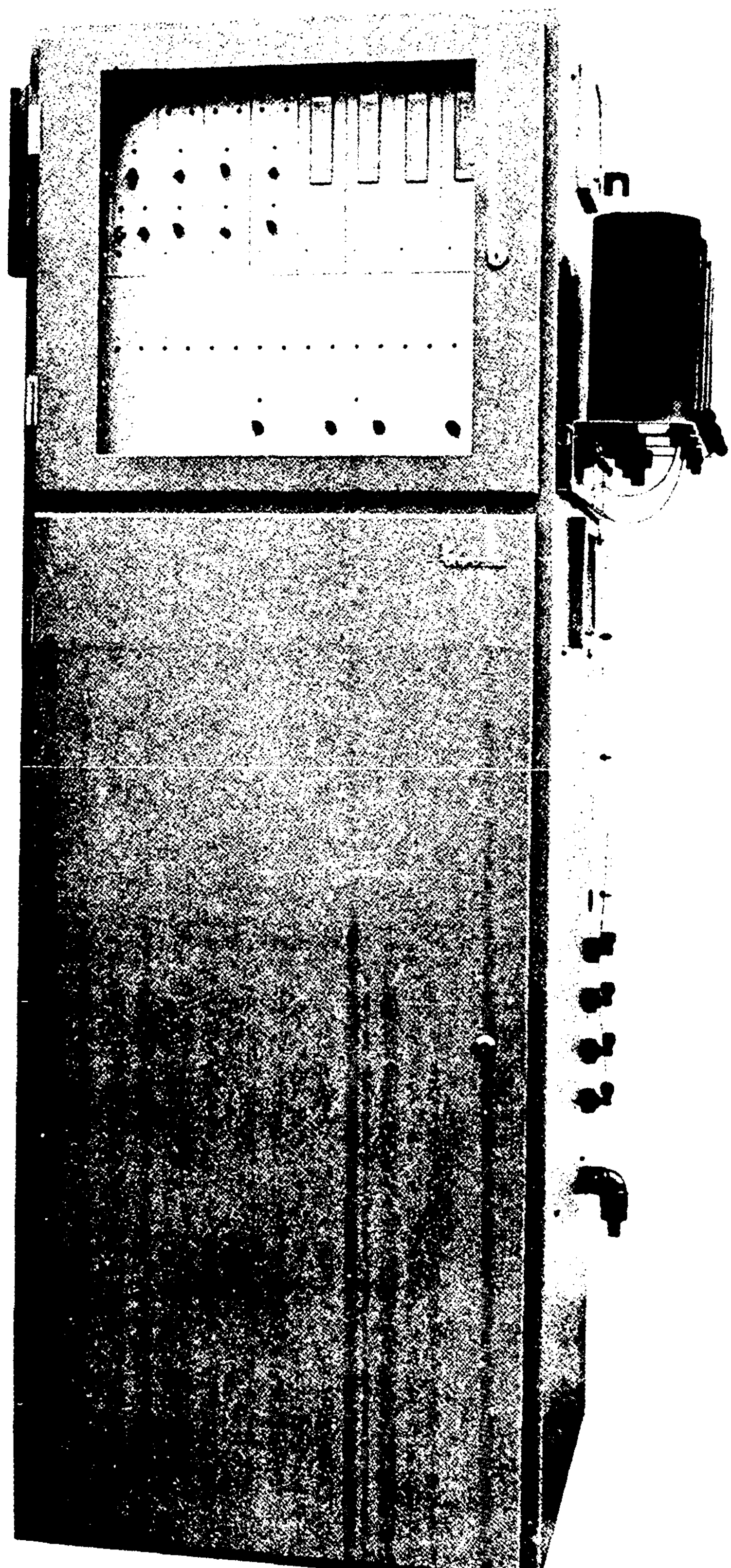


Fig. 12

In situ sodium hypochlorite preparation

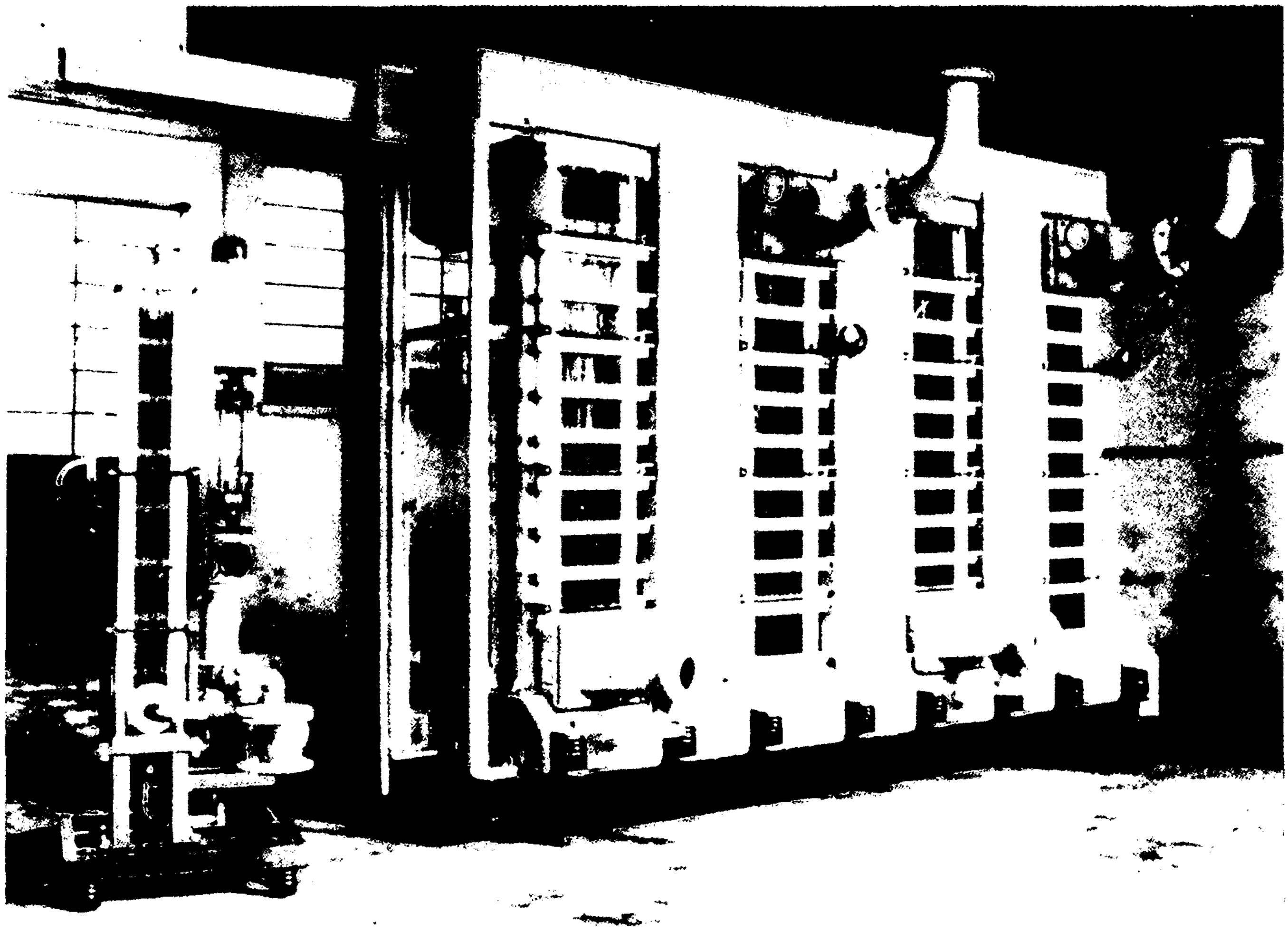


fig: 13

TURBIDIMETER CONTROLLED DEVISE FOR AUTOMATIC SLUDGE EXTRACTION

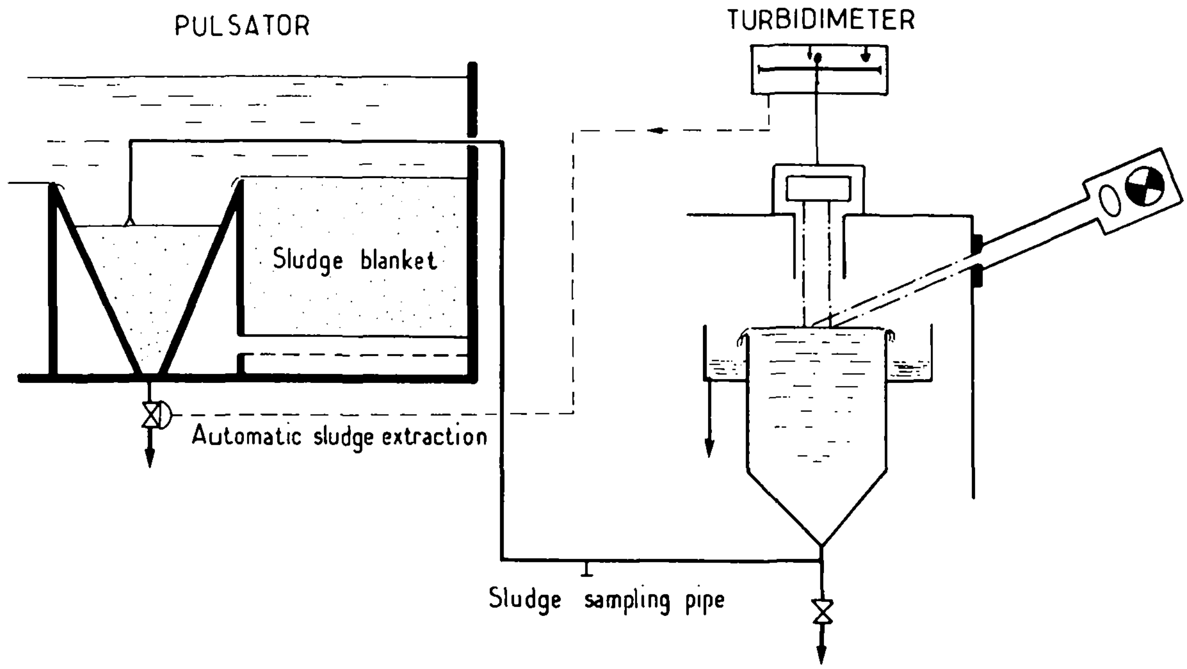
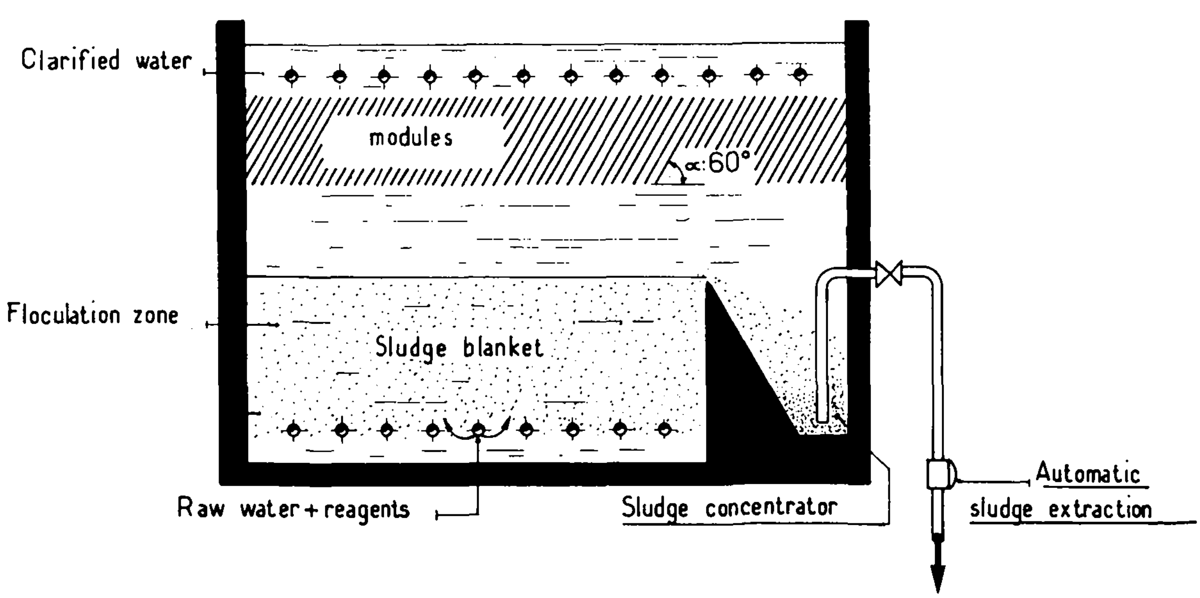
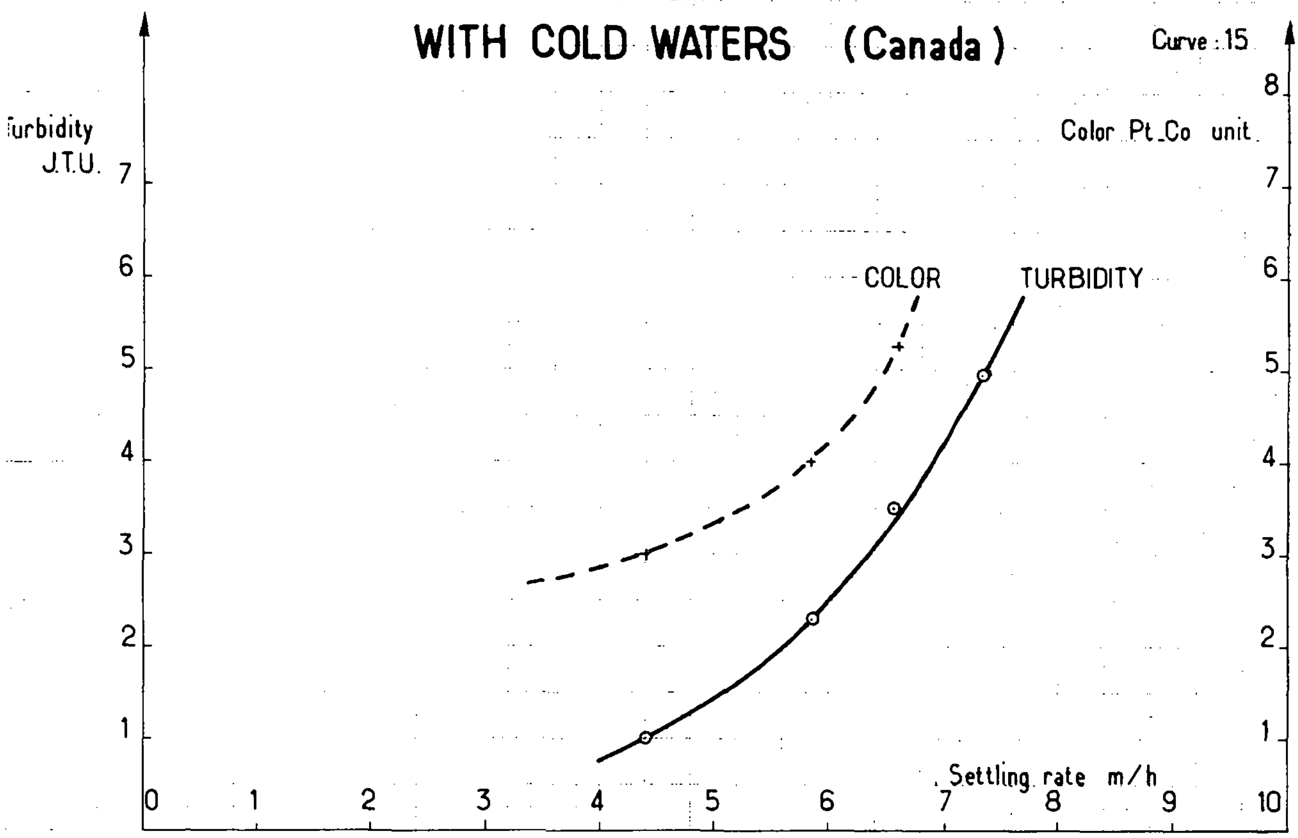


fig: 14

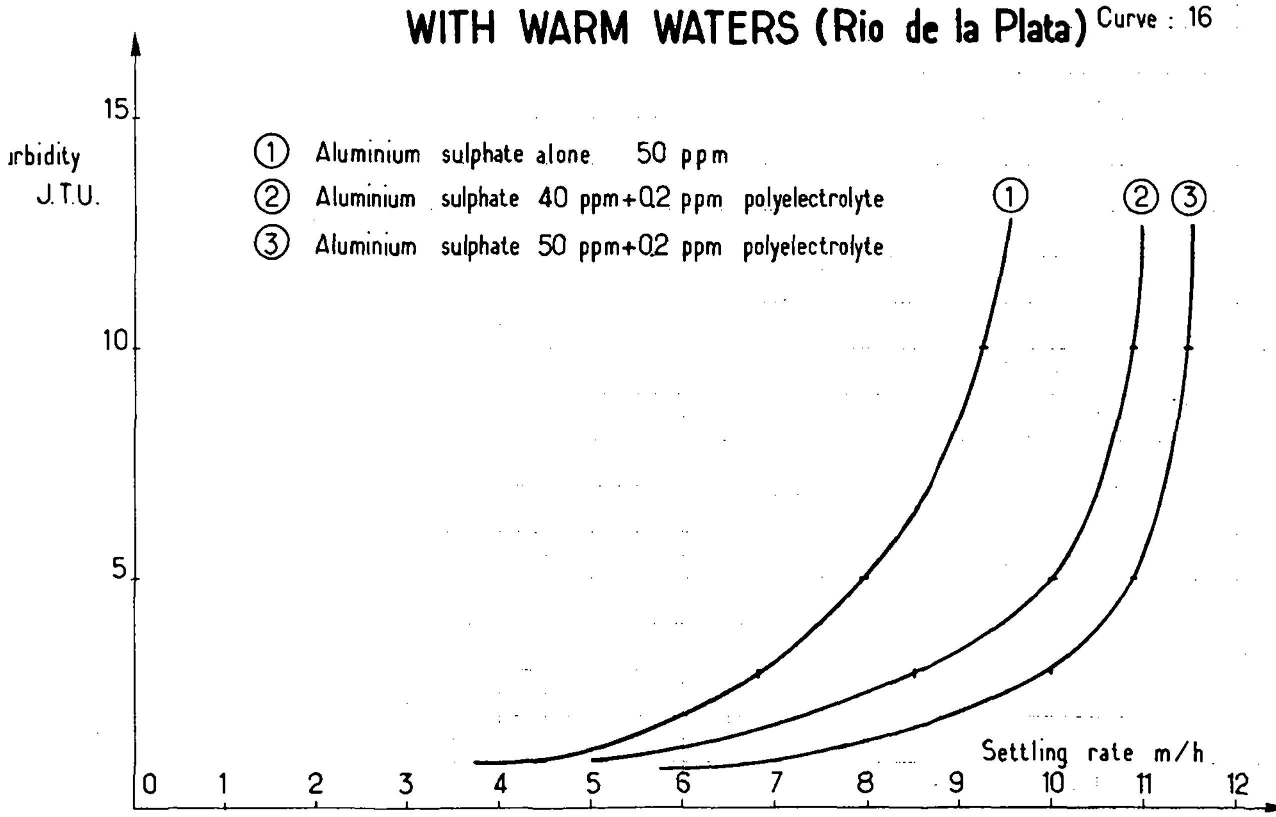
PULSATOR WITH MODULES ABOVE THE SLUDGE BLANKET



PULSATOR WITH MODULES ABOVE THE SLUDGE BLANKET WITH COLD WATERS (Canada)



PULSATOR WITH PLATES ABOVE THE SLUDGE BLANKET WITH WARM WATERS (Rio de la Plata)



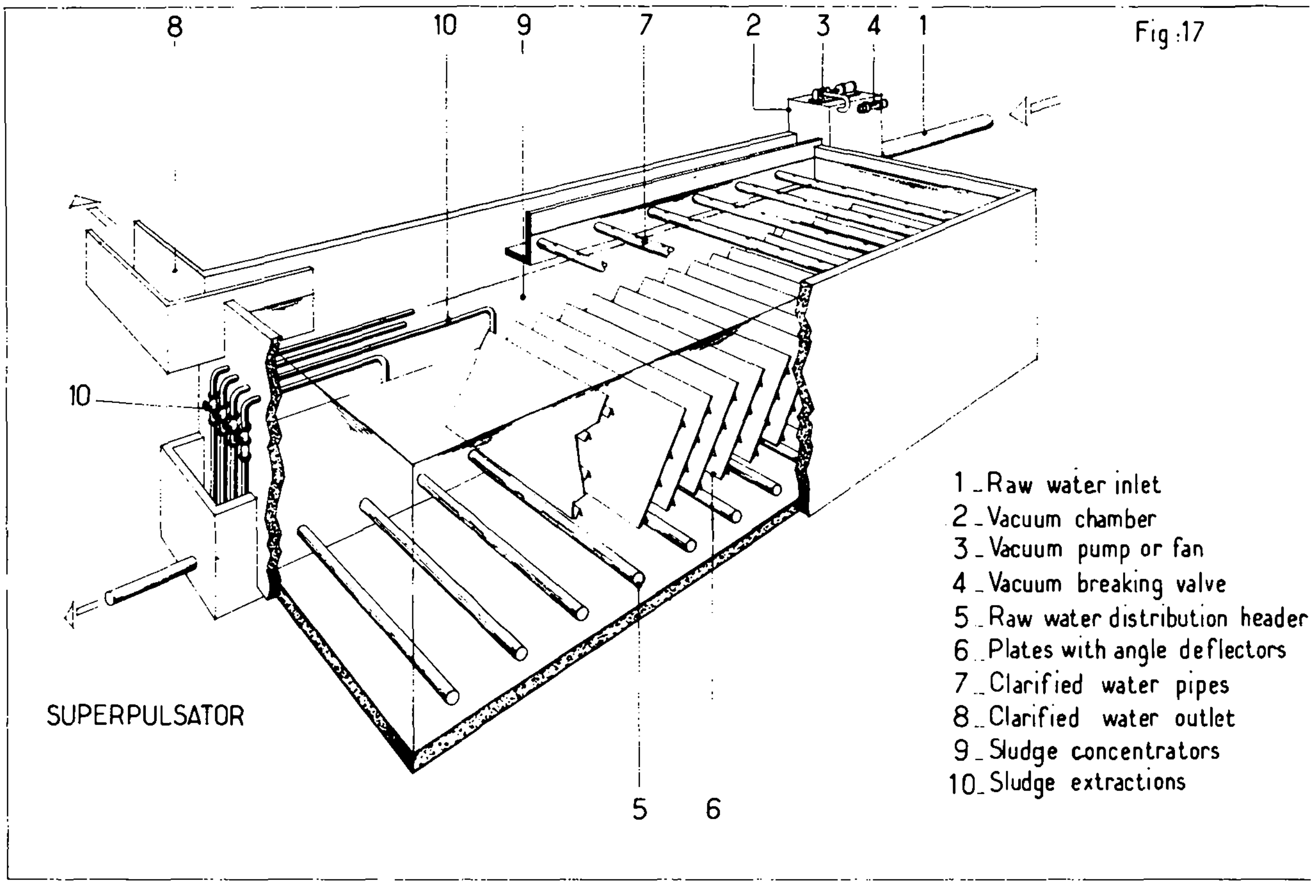


Fig :17

Fig n° 18

SUPERPULSATOR_ PLATES

WITH ANGLE DEFLECTORS IN THE SLUDGE BLANKET

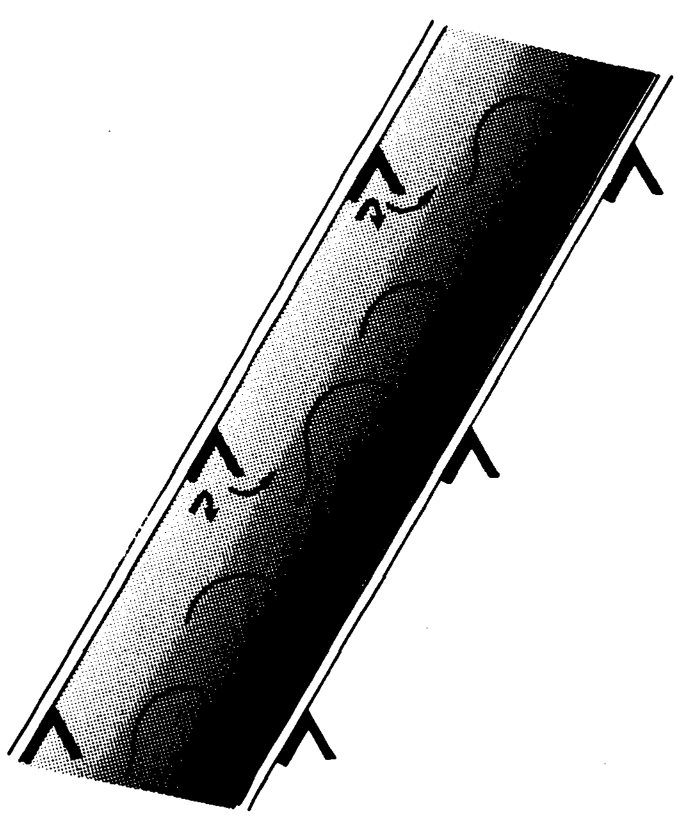


Fig. n° 19

PULSATOR / SUPERPULSATOR COMPARISON

% of sludge concentration in the sludge blanket

Type of PULSATOR rate over the sludge blanket	Suspended solids in the clarified water – mg/l	% of sludge, by volume, in the sludg blanket after 10mn of settling
Standard pulsator – 4 m/h	1.5 à 3 mg/l	36 %
Superpulsator – 4 m/h	0.8 à 1 mg/l	52 %
Superpulsator – 8 m/h	1.3 mg/l	31 %

PLATE TYPE PULSATOR / SUPERPULSATOR COMPARISON WITH WARM WATERS

Curve : 20

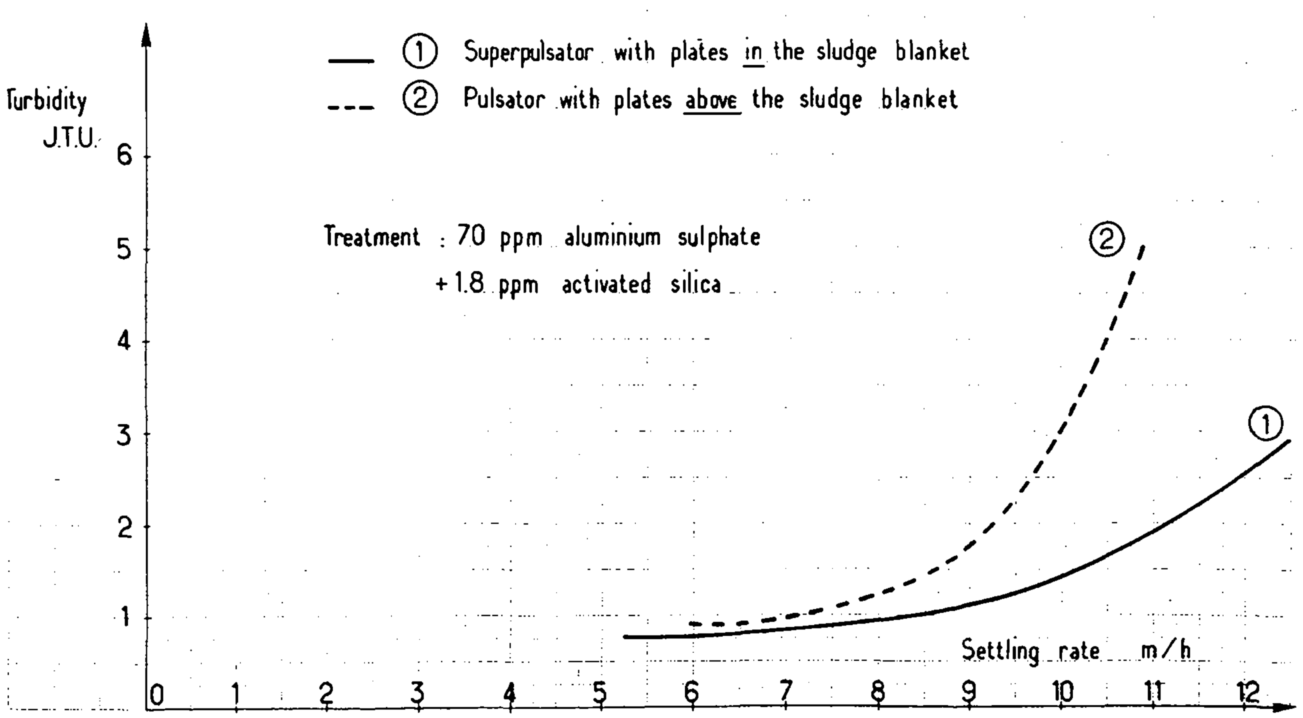
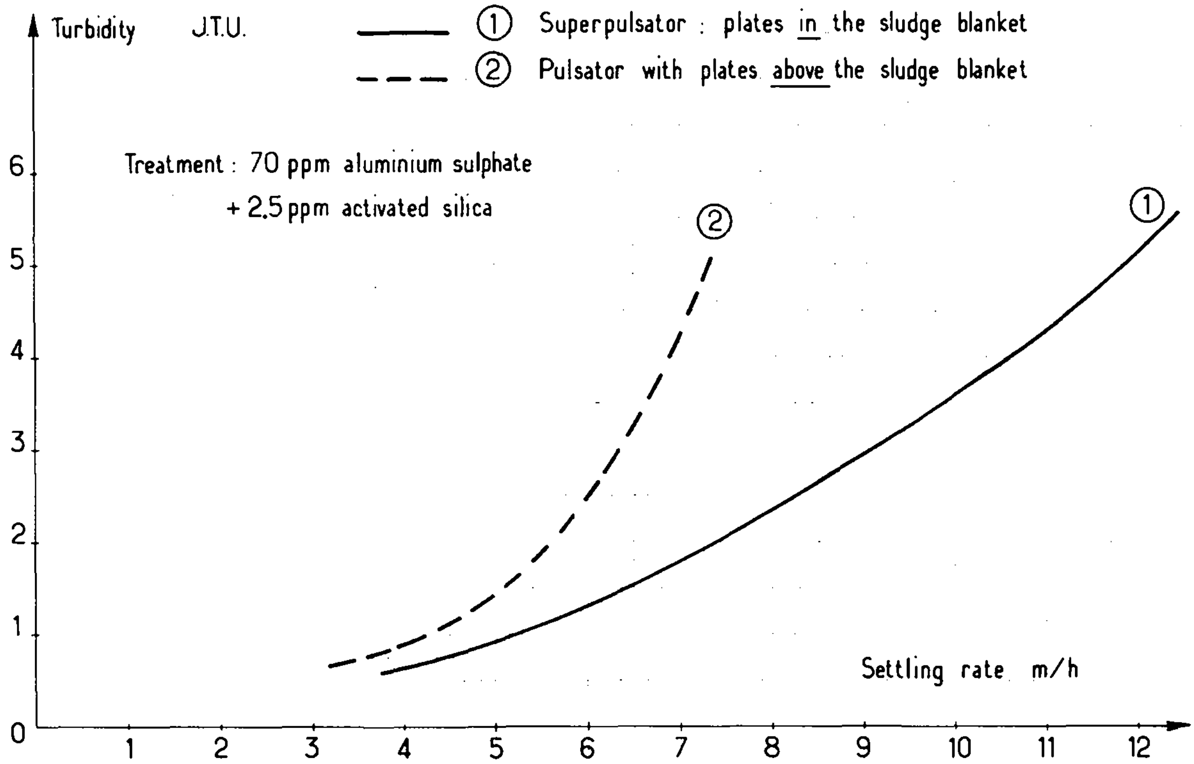


PLATE TYPE PULSATOR / SUPERPULSATOR COMPARISON WITH COLD WATERS

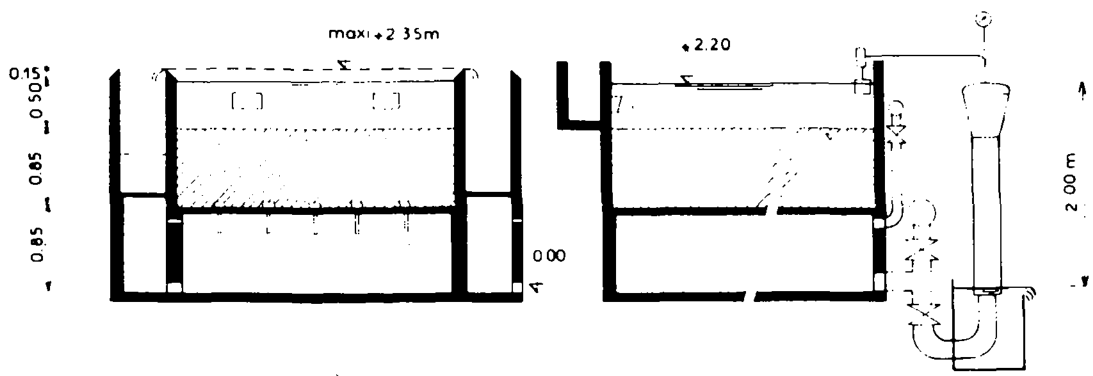
Curve n° 21



Graphique n° 22

AQUAZUR T FILTER

FILTRATION RATE 5 m/h
WATER DEPTH ABOVE THE SAND 0.50 m MAXI
SAND: EFFECTIVE SIZE 0.95 mm



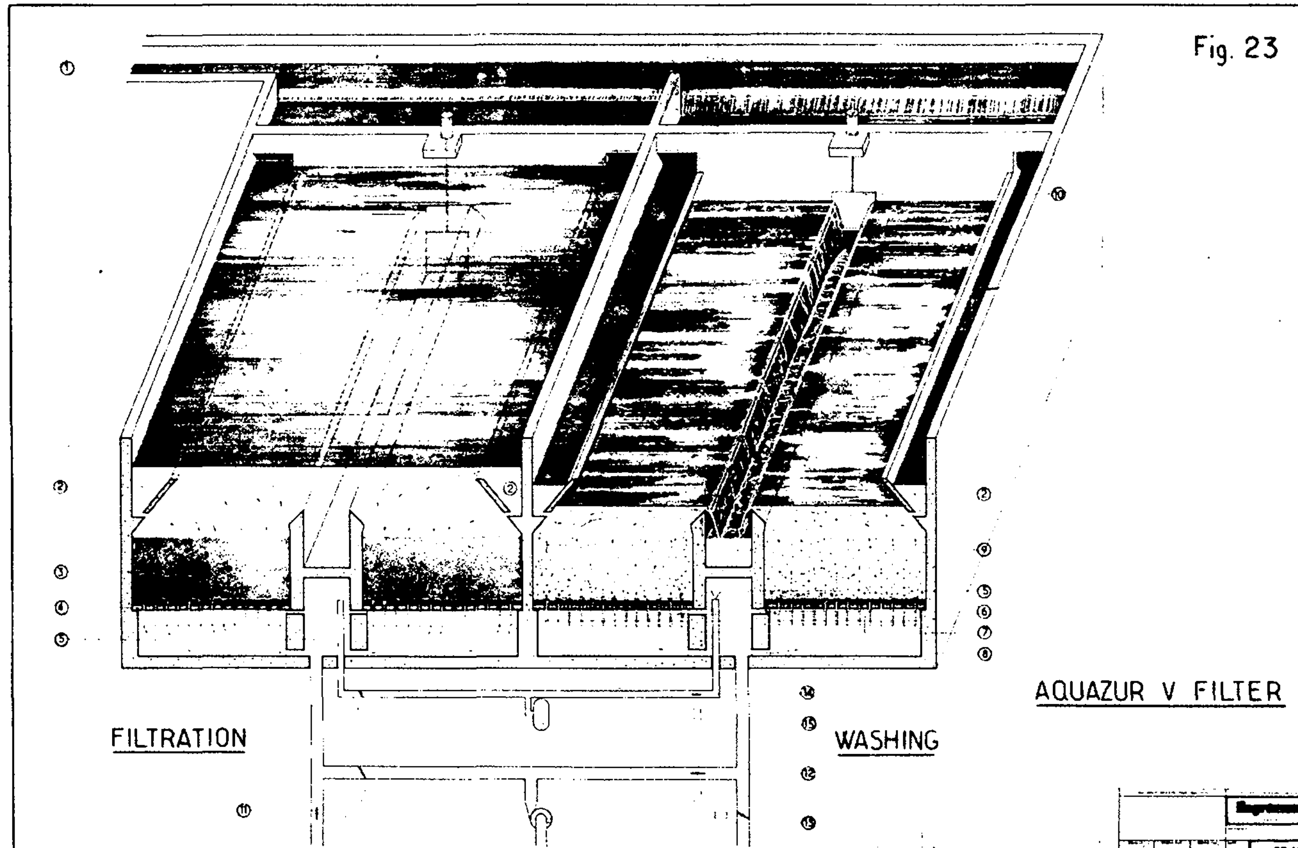
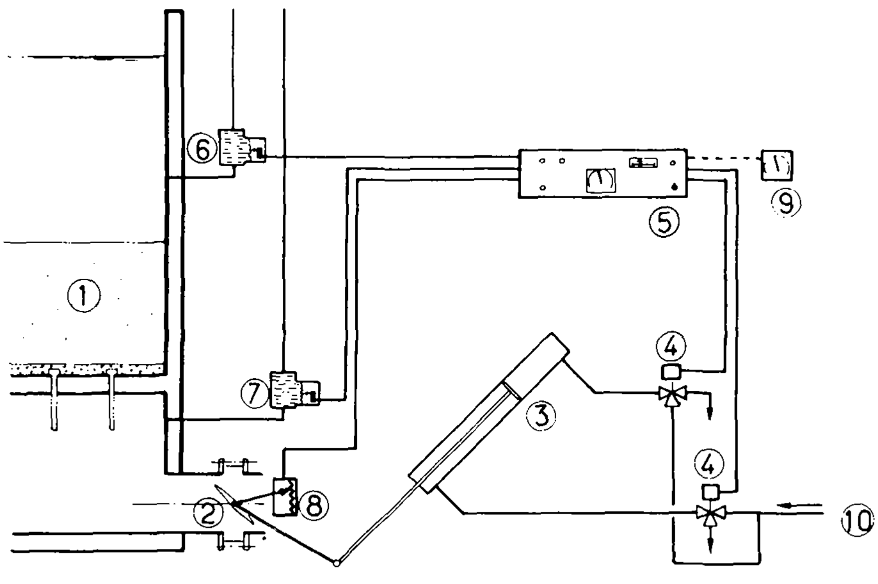


Fig. 23

AQUAZUR V FILTER

Fig. 24

ELECTRO_HYDRAULIC LEVEL CONTROLER
RNC TYPE



① Filter

② Regulation valve

③ Valve operating cylinder

④ Solenoid valves for cylinder control

⑤ Electronic rack

⑥ Level sensor (RN)

⑦ Clogging sensor (IC)

⑧ Potentiometer

⑨ Remote clogging indicator

⑩ Under pressure water

fig. 25

SLUDGE TREATMENT AT A DRINKING WATER PLANT WITH CLARIFIERS AND FILTERS

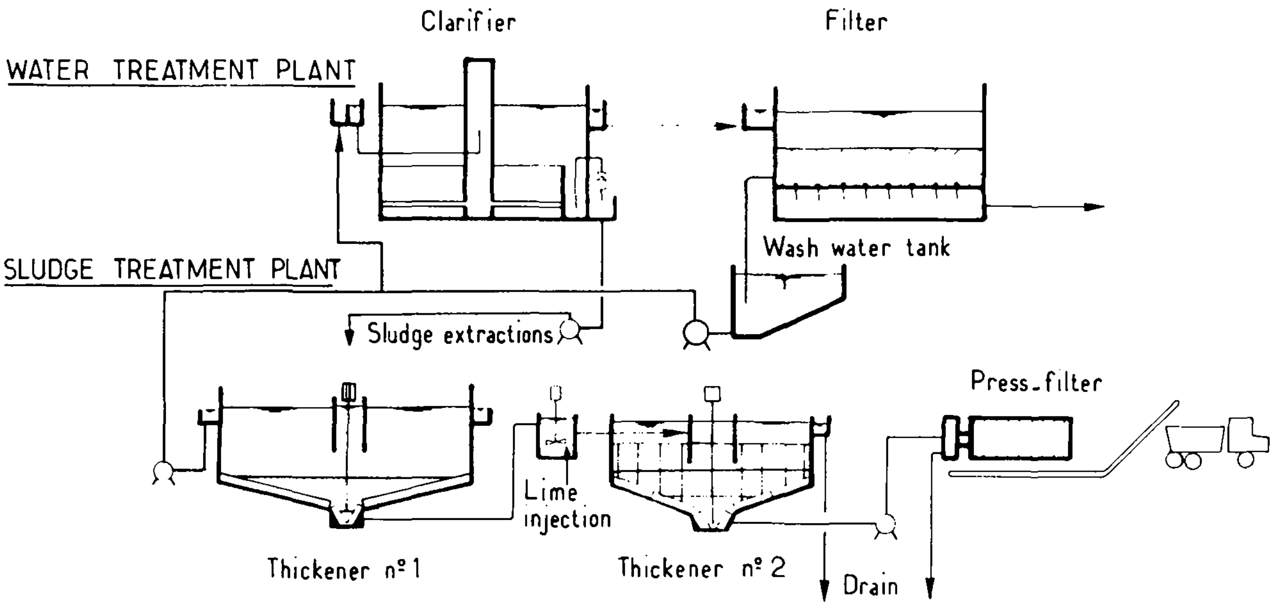
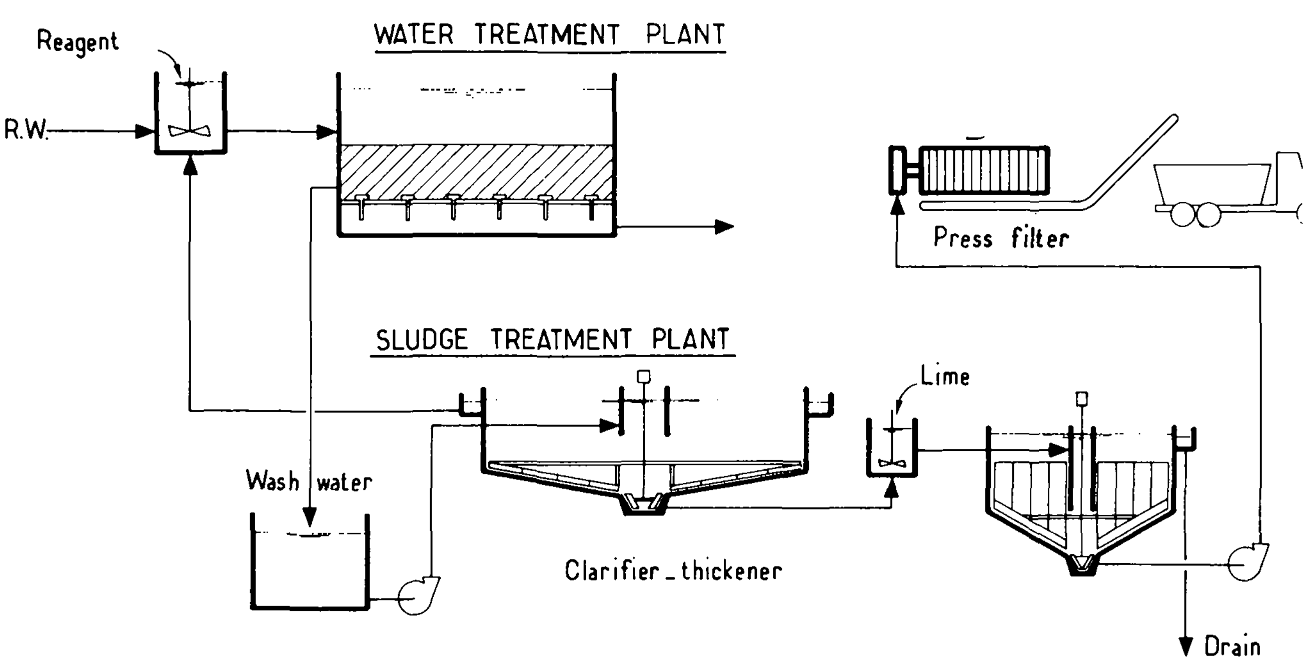


fig. 26

SLUDGE TREATMENT AT A DRINKING WATER PLANT WITH COAGULATION ON FILTERS



Paper 3d

Appropriate Technology in the Professional Literature

A contribution submitted in absentia by Dr. D. S. Mansell, Civil Engineering Department, University of Melbourne, Australia

Engineers can make appropriate choices when they are aware of the available alternatives and the constraints which apply to them. I wish to make the case now that there is room for improvement in efforts to inform them on the alternatives and the constraints which are important in the region served by this Conference.

Information on these matters is obtained firstly from undergraduate courses, secondly from practical experience and thirdly from the engineering literature.

The majority of the world's engineering education establishments reward sophistication and "stunt" technology (to use Schumacher's term[1]) and are tied to a profession which is only beginning to create decision models which include social consequences. So there will be an appreciable time lag before an effect on engineering practice can be exerted through engineering education.

Much worthwhile improvement in engineering practice is created by those engineers actually involved in designing, commissioning and operating projects. But the spread of innovation of this kind is restricted by the lack of a means of communicating it. This brings me to the third source of information - the professional literature - which is at present seriously deficient in balance. It is biassed in favour of the clever and the complex and shuns simple "appropriate" technology.

Young members of the profession need information on details of practical problems in design and construction, with appropriate solutions. All members of the profession need to be more aware of social and cultural limitations to engineering decision. Information of the first kind is rarely recorded unless it is novel or large in scale, and information of the second kind is alluded to in a cursory or patronising manner in most of the publications with large professional readership.

There is a special technical literature discussing these topics[2,3] but it makes little impact on the majority of engineers involved in Third World projects because they are unaware of it, unable to obtain it or do not appreciate its value. The task of using any other means to transmit information through the vast Asian region is formidable[4], although the Asian Institute of Technology is taking new initiatives in specialist technical fields.

The cause of a more sensitive and enlightened practice of engineering would be advanced if this Conference could increase the acceptability of "soft" technology papers in media such as the Technical Notes in the journals of the American Society of Civil Engineers.

Two papers[5,6] touching on cultural effects in engineering have been accepted recently for publication in "Engineering Issues" which is the Journal of Professional Activities of A.S.C.E. That journal contains many papers on social and economic factors in engineering decision, and the more "newsy" journals of the professional societies, such as Civil Engineering, New Civil Engineer, and Engineers Australia publish short informative articles on applications of technology and on its impact. But one cannot help feeling that more progress will be made when the person who habitually reads only "technique" papers is confronted in the same journal with examples of appropriate technology applications and information on social and economic criteria for decision.

The Conference could decide to discuss this matter and to resolve to express an opinion on it in the interests of the large Third World population which purchases its technology from engineers lacking awareness of the whole set of circumstances surrounding their work.

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Paper 4a

Funding and Paying for the Construction and Operation of Water Utilities

by Richard Timothy Whiteley

In developed countries, the Water Industry, that is water supply and waste water disposal, is the most capital intensive of all the Utilities. The Regional Water Authorities in the UK spend 50% of their income on interest and repayment of debt. In the less developed countries, capital is frequently scarce so that as much available capital as possible should be kept for other industries, which may help increase the national wealth, though as infrastructure water is essential. In many countries there is considerable unemployment so that labour-intensive techniques, rather than capital-intensive ones should be sought. I must emphasise straight away that this does not mean choosing second-best. Simpler technologies that have worked well for many years will continue to work well while more sophisticated technologies developed recently may be totally unnecessary. The more experienced labour becomes, the more automation should be considered.

Some of the newest science has been produced solely to deal with problems brought about by the carelessness and neglect of some advanced industrial countries. They have made their own problems by polluting their water resources and considerable expense is needed to correct the situation. Careful monitoring to prevent deterioration is vitally important.

PROGRAMMING WORK

In order to reduce the quantity of finance needed to get the system started, it is important to get the programming right. Though it would be ideal to know what the end will be, 15 to 20 years ahead - i.e. the quantity of water required, also the size of the distribution system, it is much more important to consider the beginning. It is very unlikely, even supposing you know the projected size of the planned development, that you will have a really accurate forecast as to the speed of growth of that development. Both speed and final size will depend on many factors which may well include the international economic climate. However, capital charges and some revenue expenditure will be inevitable from the moment the start on construction is made.

If both the treatment works and also a distribution system can be designed in phases to fit in with the development, then this should be done. The economic benefits of size are often exaggerated as well as frequently needing greater skill in management. If it is an existing development that is to be supplied with water, then even so it is better to do it in phases rather than to cover the whole development all at once. By this phasing a great deal can be learnt about the management and running of a water distribution system. The optimum size is the biggest that you have the expertise to run. If a consultant designs what should be the most economic source it will rapidly cease to be economic if not run as they designed it. This is not just a problem for less developed countries. In many countries where the skills ought to be available, many works are running at far less than design efficiency through lack of skill. I am not qualified to discuss in detail the best design, but there are several fairly obvious points which I can mention. Local materials should be used. This saves both foreign currency and time. If local energy supplies are limited or expensive, do not use high energy materials, such as cement, more than necessary. Also keep to a minimum the energy requirements for operating the plant. Energy is likely to get more expensive in real terms over the next few years.

A good, wholesome water supply is needed for three main purposes - domestic, industrial and agricultural. Agricultural use is outside the scope of this Paper and though much may be needed for irrigation, it need not be up to potable standard. In most countries the domestic demand, and that for industry, are met from the same distribution system. Having stressed that it may be sensible to be as little capital intensive as possible, even so some capital will be needed. There are four main sources from which this can be provided:

Firstly - GRANTS OR SUBSIDIES

Secondly - LOANS

Thirdly - CAPITAL CONTRIBUTION

and Fourthly - SELF-FINANCING

These sources are not exclusive of each other and the art must be to get the right mixture to suit each situation. Economics is about choice. If you have no choice, the initial problem is solved.

GRANTS OR SUBSIDIES

Whether a Government decides to help finance a water undertaking is a political decision and therefore the problem of that decision is not for me to decide. However, if such a decision has been taken, it is sensible to consider the most beneficial method for the water undertaking. Government grants are normally related to specific standards, or to ensure that the poorer areas of their country are given some assistance.

To the economist, nothing is free, so that even a grant costs somebody something. Capital grants in some countries are tied to a particular technology. Great care should be taken before accepting the grant, that the technology stipulated is appropriate in each instance. Otherwise any grant will be expensive in the long run. I would suggest that if Government funding is available, a capital grant is the most suitable. I am a great believer in a public utility having full responsibility for its own economic welfare. Though there may be strings attached, an undertaking will have greater financial freedom by a once-and-for-all grant than by periodic subsidies. Grants may be given for initial financing or for specific reasons, such as an excessively long main to supply a distant village which might not by itself be an economic proposition, but which the Government is prepared to help finance to further its own social or industrial policy. Subsidies just to fill the gap between expenditure and income are normally a mistake, as they reduce the incentive for financial discipline. However, if the Government wishes to assist old people or those on low incomes, a subsidy may be appropriate, but should be clearly shown to be for that specific purpose.

LOANS

Obviously in different circumstances loans may be available, nationally from the Government, or internationally from agencies such as the World Bank or Asiatic Bank. As a generalisation it is unrealistic to expect to get commercial loans unless the lender can be shown that he will be re-paid, plus interest. In practice, this probably means that there is an existing undertaking which is fairly prosperous, or likely to become so. Interest rates could well be high and might be variable. Security will be required and consideration must be given to exchange rate fluctuation if the loan is not in your own currency. A national loan is likely to be easier. Many Governments have their own agencies to supply capital to public bodies. The interest rates are usually fixed for the period of the loan and the length of the loan and repayment terms are decided for you. In that case you will be aware from the outset what the liability is. However, each loan may be open to negotiation. A loan can be either by way of mortgage or for repayment at maturity.

If the expected life of the asset is likely to exceed the life of the loan, then a maturity loan may be more appropriate, provided the re-financing loan is available at the expiry date. This might well be the case with a reservoir. If the asset is seen to have a limited lifespan, then a mortgage with annual repayments may be best.

The problem here is the old one. Should this generation pay for everything, so that the next, which may be richer, inherits assets free of debt, or should each generation pay for what it consumes. It is certainly the hope of people in less developed countries that their children and grandchildren will be better off than they themselves. The difficulty is that in assessing the expectation of life of many assets, it is not easy to be accurate, and whereas pipes may last many years, the pumps which push the water through those pipes will wear out much sooner in most cases. It may be sensible to average-out the expected life of all assets and a period of 50 years is reasonable.

There are, of course, various international agencies specifically set up to help finance projects in less developed countries. There undoubtedly was a time when such agencies seemed to be aiming at too much sophistication in their recommended technologies but this has now changed and considerable help and advice is usually given, as well as finance. It is also quite usual for part of the sum to be set aside for training - this I believe to be essential. Such loans are normally negotiated at Government level.

CAPITAL CONTRIBUTIONS

These can be appropriate either in the case of new undertakings or new customers with existing undertakings. If there are developers who wish to receive a water supply, there is no reason why they should be allowed to do so on the cheap. If there is existing spare capacity in the distribution system and treatment plant, it has cost something to provide it, and may well have been paid for by the existing consumers who put a further demand on the system. If newcomers take up that spare capacity, it then ceases to be available for others. Capital contribution can be paid in kind. By capital contribution I do not mean just a connection charge. I mean buying their share of the present assets, or contributing a capital sum for the provision of new capacity. They also must pay for the physical connection.

SELF-FINANCING

Self-financing is vitally important. Ideally, if capital contributions can be levied and if there is a flexible policy of self-financing, there is no reason why water rates and charges should rise in real terms, if prices are correct to start with.

It is frequently said that all new or improved assets should be paid for by borrowed money, and all replacements paid for by way of self-financing. This is too simplistic. It is frequently impossible to divide improvement and replacement. In practice at the end of any asset's life, it will be replaced by one that is more up-to-date or better in some form. In reality, the proportion of capital works funded by money taken from income must depend on the ability of the customer to pay over and above the absolute minimum necessary to keep the system operating and the undertaking solvent, but if all capital has to be borrowed at the sort of interest rates usual today, the burden of debt repayment will be considerable.

ACCOUNTING POLICIES

It is vital from the beginning for proper accounting policies to be adopted. Whether an undertaking belongs directly to the Government or is an independent public body or a private company, it is important that the organisation itself should be able to see whether it is making a genuine profit or loss. The only subsidies which are always bad are hidden subsidies. If the undertaking is an arm of the Government, it is still making a loss if its total revenue does not cover its total economic costs year by year. With proper accounting policy, any loss cannot be hidden in overall Government financing. As I have written earlier, there may be arguments for putting off some payments until the economic climate improves, but this should be a conscious decision and not just happen by chance. The problem of what to charge for depreciation of existing assets is a case in point. In a reasonably rich country with established industry, depreciation should be charged at the current cost of replacing the assets, but with a country trying to encourage investment to provide a brighter future, it could be argued that depreciation would be sufficient if by the end of the life of the asset, the original loan has been repaid. In either case, there is not necessarily any advantage in building up a fund from money provided by depreciation. Anything left over after the agreed repayment of the capital might just as well be used for future investment in your own undertaking. Any such fund would otherwise have to be left either to a Bank or invested in someone else's enterprise, and that might not be as successful as yours.

CHARGES AND PRICES

There are almost as many different tarriff structures for paying for water as there are countries in the world. A public service must be paid for by general taxation. We are not concerned here with direct abstraction, either for industrial purposes or agricultural irrigation, but if charges for these are levied, then it is usual to take into account how much water may be returned for others to use and at what quality it is returned. For piped water I am assuming there is a unified system and that domestic and industrial consumers receive the same quality. I pointed out at the beginning that water supply is usually capital intensive. That being so, there will be all the depreciation and interest to pay whether anyone takes any water or not. Therefore, if the true cost is to be charged to each consumer, he owes something to the undertaking, even before a tap is turned on. The undertaking has had to lay the pipe, build the treatment plant, etc., in order to make the supply available. It is therefore quite reasonable to make the charge in two parts, the first part for availability and the second to cover the cost of the volume of water taken. Into the second part of the charge will go those costs associated with volume, i.e. energy for pumping, any chemicals used and any expenditure for providing raw water resources. For this to be at all fair between consumers, a water meter for each consumer will be needed. If this is not possible in more undeveloped or remote areas, the costs can be recovered some other way, possibly by way of a property tax. The alternatives are to charge for numbers in any one household or even by way of the number of taps or water using equipment ineach house, but both of these systems are open to abuse and it is difficult to show that either are equitable. If, however, the expertise and sophistication is available, it is worth considering moving away from the accountants' ideas of simply covering all proper costs and moving on to those of the economist. This deals more with the value of the water to the consumer and in particular the cost of any further increase in demand - this is called marginal pricing, and is certainly worth considering where there is a shortage of water and the cost of providing another resource would be great.

The purpose of the system is to let the consumers decide whether they wish to spend more of their available income on water or on some other alternative benefit. Others are dealing with appropriate technology, science and engineering, and I am inclined to think that also in charging there is an appropriate technology.

Water can be paid for at a uniform price for everyone - so much per thousand gallons, or there can be an increasing or decreasing tarriff. It used to be usual to adopt a decreasing price as costs usually fall as greater quantities are taken. But today, with so many parts of the world realising that good sources of raw water are limited, it is now more usual to adopt an increasing tarriff and this is done in blocks so that the first block of the tarriff is fairly cheap and this will be designed to cover the essentials, such as hygiene, cooking and drinking. Then, if anyone wants to use more water for less necessary purposes, they must pay more.

When considering what tarriff structure to adopt, there are several considerations to take into account:

1. The cost of collection

2. The ease of collection and calculation

3. Whether the customer can understand the system, and the make-up of his charge.

1. COST OF COLLECTION

In any new domestic development, an individual water meter is likely to be installed. This means that each meter must be read regularly. If it is read only once a year the cash flow to the undertaking will be very slow; also a water meter has to be maintained. An individual account will have to be calculated and records kept. Where water charges are levied by way of a water rate on property, the cost of collection is approximately 2%. Where water meters are installed, these costs rise to about 4% of the money collected, but the greater number of meters, the lower will the cost fall.

2. EASE OF COLLECTION AND CALCULATION

Water meters will have to be placed at a convenient spot for reading. If they are in the house someone may have to be there to let the water meter reader in. If it is a cold country, then any meters outside will have to be below frost level.

A very detailed and complex charging system may please the economist, but can easily be a great problem for fairly low level staff who have to make the calculations. Schemes designed to charge for seasonal differences in demand involve very definite meter reading times. An inverted block tarriff system also requires calculations. Therefore choose a simple system which will be cheap to adminster.

3. UNDERSTANDING BY THE CUSTOMER

Many people still seem to think that water is free or should be so that if payment is to be made, at least fairly willingly, the customer must understand the system. On the whole, people prefer to pay solely on volume and do not always understand why they should pay for availability as I have explained above. Also to levy charges on the basis of long-run marginal cost pricing, though it may lead to the correct allocation of available resources, is not a very easy concept to explain or indeed to calculate.

If the United Nations Drinking Water Decade in the 1980s is to be successful, three components are necessary: Construction, Training and Finance. This is a trio that must all be working together if anything is to be achieved.

In many ways the first - CONSTRUCTION - is the easiest. Consultants and design teams are available. The second - TRAINING - is also important, so that after construction any new project can be run efficiently.

The third - FINANCE - is in some ways the most important. It is important to raise the necessary money to get the projects built, and just as important to work out a realistic policy for paying for that finance, so that a charging structure and price level must be considered from the start.

Paper 4b

Financing Water Supply Development and Operations in West Malaysia

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SYNOPSIS

The provision of safe water supplies in West Malaysia is the responsibility of each State Government. Except for two States which have Water Boards each State constructs and manages its waterworks through its State Public Works Department (PWD) with technical assistance and support from the Federal PWD. The Federal Government plays a very important role in the water supply development of the country. The major capital projects in the States are implemented by way of loans and manpower assistance provided by the Federal Government. To meet increasing demand of potable water by its growing population and to cater for industrial uses the Federal Government has earmarked substantial funds under its Third Malaysian Plan (1976-1980) to provide grants and loans to the respective State Government as well as to the different implementing statutory authorities. The paper describes the types of financing plans prevailing in the country. In all circumstances the State PWD takes over the project facilities on completion and mans and manages the water supply system thereafter. Water charges are levied on metered connections and all revenues collected belong to each State Government concerned. The concept of beneficiaries paying for water service through adequate water rates is well-established. Cross-subsidisation between urban and rural system is practised by maintaining uniform water rates throughout each State.

INTRODUCTION

Malaysia, with a population of about 12 million is a federation of 13 States occupying two distinct regions separated by about 400 miles of South China Sea. West Malaysia with a population of about 10 million consists of 11 States on the Malay Peninsula and East Malaysia comprises the States of Sarawak and Sabah on the north-east cost of the island of Borneo. Each State is divided into a number of districts for administrative purposes. Under the Federal Constitution the provision of safe water supply lies with the respective State Government.

The State Public Works Department (PWD) is generally responsible for the design, construction, administration, operation and maintenance of all public water supplies within the State. The main exceptions are Malacca, Penang, Kuching and Sibu which have independent water boards. Some small rural water supply systems in the State of Kelantan are operated and maintained by local councils.

At the national level, the water supply branch of the Federal PWD provides technical advice to the Federal Government and State PWDs in West Malaysia on all water supply matters. Its responsibilities include collection of statistical data on water supplies, examination of proposals on schemes for which Federal loans are requested, assistance in the design and supervision of certain projects and central procurement of materials and equipment.

Each State PWD operates the waterworks through the offices of the PWD district engineers who are also responsible for other activities such as roads, bridges, airfields, buildings etc. The water supply division which is an integral part of each State PWD is normally headed by a Senior Water Engineer who is responsible for the overall planning, preparation of detailed designs while routine matters of operations and maintenance, meter reading/billing are undertaken by the district PWDs.

WATER SUPPLY DEVELOPMENT

Water supply systems in West Malaysia are generally not restricted to serving one community, town or city. The system not only serves an area comprising mainly urban population but it also benefits the population in the adjacent areas. Most systems within a State and in some instances systems in adjacent States have been interconnected to facilitate supply. This approach has brought the benefits of piped water supply to rural communities enroute which would normally be unable to support separate piped water systems on their own..

With an average annual rainfall of about 100 inches, West Malaysia has good water resource potential to meet future agricultural, hydropower, industrial and domestic needs. At present, it is estimated that about 60 percent of the total population has access to piped water supply facilities compared with about 50 percent in the 1970 West Malaysia census. Emphasis is now given to provide these facilities to more rural communities.

The Government's New Economic Policy (NEP) which became effective with the implementation of the Second Malaysia Plan (1971-1975) is aimed at, inter alia, the eradication of poverty and enhancement of the quality of life of of all Malaysians through the expansion of various services like housing, education, health and water supply. In the Third Malaysia Plan (TMP) (1976-1980), substantial allocations have been made for water supply development. (See table below).

Table I

PUBLIC DEVELOPMENT EXPENDITURE FOR WATER SUPPLY IN WEST MALAYSIA

(Malaysia $ Million)

Type of Supply	SMP 1971 - 1975	TMP 1976 - 1980
Urban water supplies	230.4	241.9
Rural water supplies	3.8	100.0
Felda water supplies	19.7	70.4
Regional development authorities water supplies	-	84.1
Total	253.9	496.4
Source: Third Malaysia Plan		

The programs proposed under the Third Malaysia Plan (TMP) includes projects to meet growing demand of the principal urban areas of the country, expansion to rural areas, and the provision of water supply facilities to the settlers under the Federal Land Development Authority Schemes (FELDA) and the Regional Development Areas (RDA). These objectives are being pursued through the construction of new projects, augmentation of existing works and expansion of service from existing systems.

The funds for investments are derived from annual allocations in State budjets Federal grants Federal loans and external loans sought from international lending agencies like the World Bank (IBRD) and the Asian Development Bank (ADB) as well as from the Kuwait Loan Fund.

STATE WATER SUPPLIES

Each State funds its capital works and operations from the following sources:-

a) Water charges.
b) Consumer fees for connections.
c) Consumer deposits.
d) Contributions from private housing estates.
e) Federal loans.
f) External foreign loans.

Water charges vary from State to State in West Malaysia. (See table 2). Generally each household pays about 2% to 3% of the monthly income towards the cost of water supplies.

Every new consumer has to pay a deposit amounting to about 2 months consumption. By and large the average deposit is approximately M$30.

It is common practice that private housing estates have to pay for the cost of laying reticulation mains, service reservoirs, booster pumping stations, etc. or have to provide these facilities. In the first case they are charged the costing price; in the second case, after implementation, these assets are taken over by the States without payment.

The Federal Constitution lays down that a State may not borrow except under the authority of State law and State law cannot authorise a State to borrow except from the Federal Government.

Each State finances its water supply programme from voted provisions under its annual budjet. For capital works involving large capital outlay, Federal loans are obtained.

The mechanics for obtaining a Federal loan is briefly described herein. The State PWD first submits the feasibility report of the project through its State Government to the Federal Economic Planning Unit (EPU). The Federal PWD studies the report, appraises the technical soundness and financial aspect of the project and advises the Federal EPU accordingly. The recommendations of the Federal EPU will be forwarded to the Estimates Sub-committee of the National Development Planning Committee (NDPC) for consideration.

Approval for the project is followed by the signing of a loan agreement between the State Government and the Federal Treasury. The loan agreement sets out, inter alia, the interest rate payable, the loan repayment period and the loan withdrawal schedule.

The Federal EPU also decides on the type of loan financing, whether a project is to be fully financed from Federal loan or a combination of Federal loan and foreign loans. No water supply project in this country has yet been fully financed from a foreign loan and foreign financing is normally limited to the foreign exchange component of each project.

In the case of foreign loan financed projects the project will be executed by the State PWD, sometimes with free technical assistance by way of detailed engineering design, calling of tender and tender evaluation from the Federal PWD. The Federal PWD also seconds engineers from its pool of engineers to the States to assist in project supervision. Where the Federal PWD is unable to assist, the State PWD employs local or foreign consulting engineers to design and supervise the project. In the latter case, the Federal PWD's role is to assist in the preparation of terms of reference, evaluation of consultant's proposals and final selection of the consultant for the project. The consultant fee for detailed design and construction supervision is borne by the State Government.

RURAL WATER SUPPLIES

Up to 1973 all costs towards rural water supply projects were borne fully by the respective State Government. But in 1974, the Federal Government realising the financial constraints of the States to provide safe water supply facilities to the rural areas where economic returns are poor decided to assist the States by way of financial subsidy towards the cost of implementing such projects. The subsidy was on a modest scale and little headway was made in this programme.

However, in the Third Malaysia Plan (TMP) (1976-1980) the Federal Government allocated $100 million towards the rural water supply programme with an undertaking that more funds would be forthcoming under its mid-term review. This interim allocation works out to be more than 25 times the provision that was in the Second Malaysia Plan.

The primary objectives of this programme, which conform to the Government's New Economic Policy , are to provide treated water supply to more rural people so as to uplift their economic and social well-being as well as to redress the economic imbalance between the different States.

Under this programme the States in the country have been classified by the Federal Government as 'deficit' and 'non-deficit' States. The 'deficit' States are eligible for full grant and for the 'non-deficit' States two-thirds (2/3) of the total cost of each project would be financed by the Federal Government while the other one-third (1/3) would come from the State Government. With the introduction of this financing formula in 1977 the lion's share of the total provision goes to the 'deficit' States.

The scope of water supply development works that can be financed from this source of funds is wide. It allows each State to extend its existing system network to cover a wide area. Allied to such extensions, it allows the States to augment existing treatment works, to resize and add on new pipelines, and construct reservoirs and booster pumping stations. In areas which are not capable of being served by the existing or extended network new treatment plants, reservoirs and pipe systems have been designed and constructed.

Coupled with development works in other areas and with the vast programme in hand the PWD suffered certain set-backs in the implementation initially. Problems like manpower shortage, lack of sufficient pipe materials, valves and specials and insufficient contractors contributed to a slow start. However it is heartening to note that these problems have since been ironed out and given time the country is convinced that its rural water supply programme could be carried out successfully.

FEDERAL LAND DEVELOPMENT AUTHORITY (FELDA) WATER SUPPLIES

The Federal Land Development Authority (FELDA) was set up by the Federal Government to open up hitherto undeveloped land for agricultural use and settlement with oil palm and rubber as the main crops. Each land development scheme comprises about 5000 acres, out of which about 400 acres are used for village development. To-date 262 schemes have been completed involving a total area of about 1.1 million acres. The Authority borrows money from the Federal Government and also from foreign lending agencies through the Federal Government to finance its land development for agriculture and settlement and such loans are repayable over a period of 10 to 15 years at nominal interest rates.

On the other hand, the Federal Government provides a grant for the development of village infrastructures for which the Authority depends wholly on the public agencies, e.g. the PWD is solely responsible for the design and construction of roads, water supply, schools, health centres etc. for the village. The Authority advises the Federal PWD on the location of each new settlement and the initial and probable final number of families it will contain. Federal PWD provides an approximate of cost and funds are made direct from the Ministry of Lands and Regional Development.

Water supply systems are designed by the Federal PWD usually by its own staff and it assigns officers for supervision of construction. Designs provide for fully treated water supplies initially providing only a public stand-pipe supply but planned for conversion to private connection once the land scheme provides sufficient revenue per family. Through standpipe supply the settlers are provided with free water for a period of 5 years for oil palm schemes and 7 years for rubber schemes; the periods calculated from the date of planting. After the expiry period of free water supply, the standpipes are disconnected and the settlers are required to apply for metered connections to their houses.

In normal circumstances most families would be able to pay their own cost of such private connections but should any family experiences financial hardship the FELDA Authority or the State Government would provide interest free loans to the settlers repayable over a period of 2 to 3 years in regular repayment instalments.

So long as the public standpipe system is operated the cost of this service is a State Government responsibility, except that FELDA staff assigned to the project as development officers and who reside within the village are given metered connections and monthly bills are submitted. Provision is also made for metered water supplies to the processing factory and other non-resident buildings, but no fire-fighting water requirements are considered.

On completion of construction the facilities are taken over by the State PWD who mans and manages the system. No compensation towards the capital cost need be paid by the State Government and all revenue collected from water sale and connections goes to the State Government.

REGIONAL DEVELOPMENT AUTHORITIES (RDA) WATER SUPPLIES

In contrast to earlier land development schemes of the Government which provided for settlement of migrants in villages, urbanisation of settlement has by now become the accepted concept for regional development schemes. Such schemes include those for Johore Tenggara (KEJORA), Pahang Tenggara (DARA) and Trengganu Tengah (KETENGAH) on the less developed east coast of West Malaysia. (See figure 1).

Forestry and agriculture are to be the main sources of income and employment initially but are to be joined by industry and tertiary sectors at an early stage to facilitate sustained growth.

Under this concept of development new urban settlements (towns) will be created and a wide range of economic and social services and amenities such as piped water supplies, electricity, health, education etc. will be included.

These three major regional development schemes will be implemented through Regional Development Authorities (RDA) established by Parliamentary Act. Apart from its general planning, coordinating and monitoring role, each Authority is primarily responsible for the development of new towns which includes their planning, provision of town infrastructure, housing and commercial space and development of industrial estates.

Funding of water supply development in the regional development schemes appears complex. The town reticulation system is planned, designed, constructed and financed by theRDA while the State PWD is responsible for its maintenance. The RDA borrows the required funds from the Federal Treasury under a loan agreement signed by the RDA and the Federal Treasury. In order to repay the loan, the RDA assesses a charge against each square foot of saleable land.

On the other hand the trunk mains and other source development works are planned, designed and constructed by the Federal PWD which has established an implementation unit in each region. Funding of these works is the responsibility of the StateGovernment which borrows money from the Federal Government.

Foreign loans, especially from the Asian Development Bank are also obtained through the Federal Government.

However, where FELDA villages are supplied from the regional project, FELDA bears a portion of the total regional project cost which as mentioned previously comes as a grant from the Federal Government. The cost sharing ratios are worked out by the Federal PWD and is based on the ratio of projected water demands provided by FELDA and the RDA prior to tendering of the construction contracts. The ratios then remain fixed until the completion of the project, even if FELDA and RDA revise their projections.

All project facilities when completed will be manned and managed by the State Government through its State PWD. In order to meet the operational costs and debt service the State will levy a charge for all water through metered consumption.

WATER CHARGES

The concept of beneficiaries paying for water service through adequate water rates is well-established in West Malaysia. Water revenue in the majority of cases is sufficient to meet operating costs and debt service. (See fig.2). All service connections are metered. The schedule of charges includes a fixed minimum monthly charge and a rate per thousand imperial gallons, both of which are different for domestic and non-domestic consumers. These water charges are uniform throughout each State but vary from State to State (See table 2). The use of uniform charges throughout each State means that the urban systems subsidise the water supply to the population in the rural areas to some extent but it represents a practical solution for the better utilisation of the waterworks facilities.

Some State Governments encourage the people in the rural areas to have house service connections wherever feasible. To facilitate this an 'instalment plan' was initiated under which the PWD provides the house service connection and recovers the cost from the householder in not more than 36 monthly instalments. Recovery of each monthly instalment is effected by adding it to the regular water bill rendered monthly. The maximum distance from the main is generally kept under 300 feet and the average cost per connection which includes one tap in the house comes to about $180 ringgit and the minimum monthly instalment is fixed at $5 ringgit. This scheme has been enthusiastically received by the people and it has resulted in an increase of house service connections and reduction of public standpipes. The scheme also helps to improve the quality of service without additional cost to the PWD.

ACKNOWLEDGEMENT

The writer is thankful for the assistance rendered by his colleague **Ir. Lai Cheng Cheong**, Superintending Engineer, Federal PWD Water Supply Division, in providing relevent information and to the Director-General of the Public Works, Federal PWD for permission to publish this paper.

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STATES OF WEST MALAYSIA

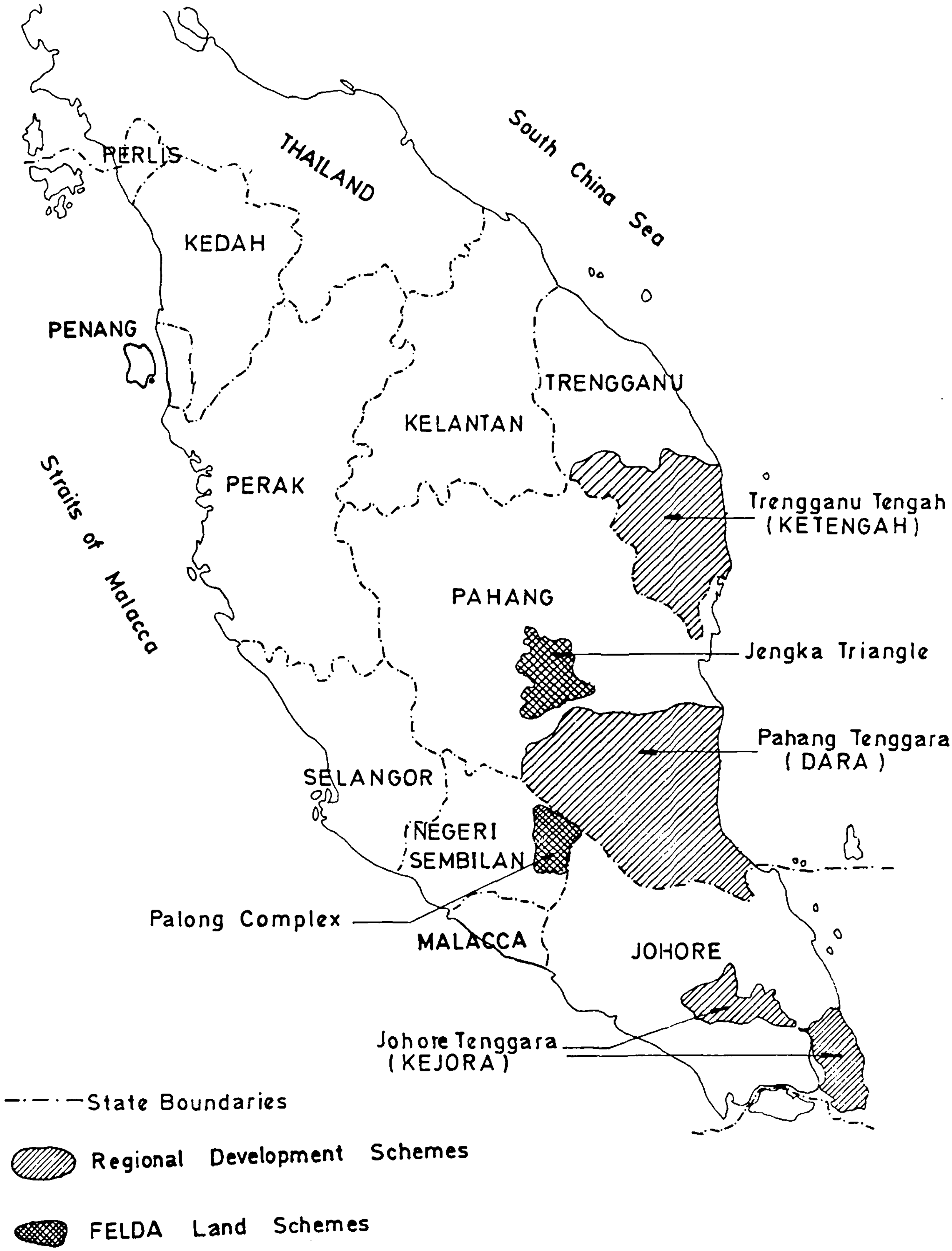

Figure 1

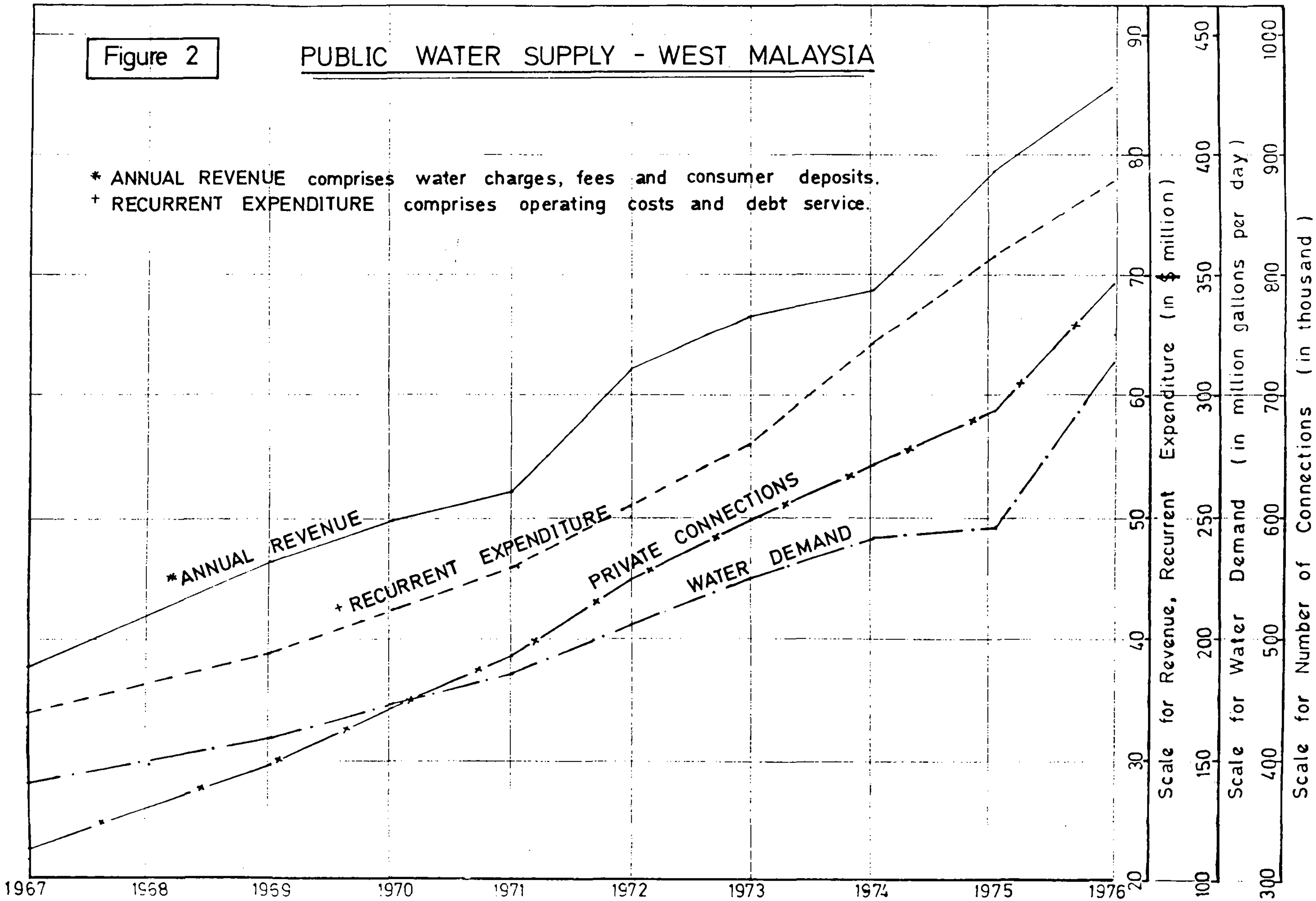

Figure 2 PUBLIC WATER SUPPLY - WEST MALAYSIA

4b12

WATER SUPPLY & RELATED SERVICES FOR DIFFERENT STATES IN PENINSULAR MALAYSIA

GROUP	TYPE OF CHARGES / STATE	SELANGOR	PENANG	NEGERI SEMBILAN	JOHORE	PAHANG
A.	DOMESTIC SUPPLIES:					
	1. RESIDENTIAL	$1.20/1,000 GAL.	UP TO 5,000 GAL @ $0.60/1,000 GAL OVER 5,000 GAL. @ $0.95/1,000 GAL.	$1.20/1,000 GAL	UP TO 5,000 GAL @ $1.00/1,000 GAL EVERY SUBSEQUANT 1,000 GAL @ $1.50/1,000 GAL	$1.00/1,000 GAL
	2. RELIGIOUS INSTITUTIONS	$0.60/1,000 GAL.	- DO -	IN EXCESS OF FREE SUPPLY. $0.40/1,000 GAL	- DO -	IN EXCESS OF FREE SU $1.00/1,000 GAL
	3. CHARITABLE ORGANISATION	- DO -	- DO -	IN EXCESS OF FREE SUPPLY. $0.80/1,000 GAL	- DO -	- DO -
	4. PUBLIC STANDPIPES	$1.20/1,000 GAL	- DO -	$1.20/1,000 GAL	- DO -	$1.00/1,000 GAL
	5. MIN. CHARGE PER MONTH	$2.40	$2.00	$1.00	$2.00	$ [illegible]
B.	COMMERCIAL SUPPLIES:					
	1. INDUSTRIAL (BULK SUPPLY RATE)	$2.00/1,000 GAL.	FIRST 5 MILLION GAL @ $1.30/1,000 GAL 5 MILLION TO 10 MILLION GAL @ $1.10/1,000 GAL 10 MILLION TO 40 MILLION GAL @ $0.95/1,000 GAL ABOVE 40 MILLION GAL. @ $0.80/1,000 GAL.	$2.00/1,000 GAL	$2.00/1,000 GAL.	$2.00/1,000 GAL
	2. CONSTRUCTION	- DO -	$2.00/1,000 GAL.	- DO -	- DO -	$1.60/1,000 GAL.
	3. MANUFACTURING	- DO -	- DO -	- DO -	- DO -	$2.00/1,000 GAL.
	4. SWIMMING POOL	$1.20/1,000 GAL.	-	- DO -	- DO -	-
C.	SPECIAL RATE:					
	1. SHIPPING	$3.00/1,000 GAL.	$3.00/1,000 GAL.	$2.00/TON	<100 TONS @ $2.00/1,000 GAL >100 TONS @ $5.00/1,000 GAL	$1.80/TON
D.	OTHER SERVICES:					
	1. CONNECTION TO PUBLIC MAIN.	UP TO 1"Φ - $20.00 1¼"Φ TO 2"Φ - ACTUAL COST 2¼"Φ TO 3"Φ - PLUS 25% OVER 3"Φ	LESS THAN ¾"Φ - $60.00 MORE THAN 3"Φ - ACTUAL COST PLUS 25%	UP TO 1"Φ - $12.00 1¼"Φ TO 2"Φ - $18.00 2¼"Φ TO 3"Φ - $24.00 OVER 3"Φ - $36.00	UP TO 1"Φ FREE OVER 1"Φ COST PLUS 25%	$50.00 FOR EACH CONNECTION.
	2. FIXING WATER METER	-	$2.00	$2.50	-	$3.00
	3. DISCONNECTION OF WATER METER.	-	-	$2.50	-	$3.00
	4. RECONNECTION OF WATER METER.	$4.00	$2.00	$4.00	$3.00	$5.00 $8.00 RESTORATION A[FTER] PAYMENT DEFAULT
	5. METER RENT	-	SIZE OF METER - RENT (FOR 1 MONTH/PART OF MONTH) ½"-¾" - $2.00 1" - $4.00 1½" - $8.00 2" - $12.00 3" - $15.00 4" - $20.00 6" - $25.00 8" - $50.00 12" - $60.00 15" - $80.00 18" - $100.00 24" - $150.00	-	-	-
	6. METER TEST	$7.50	$5.00	$7.50	$5.00	$10.00
	7. SWIMMING POOL - TEST CERTIFICATE - ANNUAL RENEWAL	 $20.00 $5.00	 $20.00 $2.00	 $20.00 $5.00	 $20.00 $5.00	 $50.00 $10.00
	8. PLUMBER'S LICENCE - ANNUAL RENEWAL	$25.00 $2.00	$25.00 $2.00	$25.00 $2.00	$10.00 $5.00	$25.00 $5.00
	9. PRESSURE TEST	$30.00	$30.00	$100.00	$125.00	$10.00
	10. METER REPAIR	ACTUAL COST PLUS 25% OVERHEAD CHARGE	-	ACTUAL COST PLUS 25% OVERHEAD CHARGE	ACTUAL COST PLUS 25% OVERHEAD CHARGE	ACTUAL COST PLUS 25 OVERHEAD CHARGE

TABLE 2

PERAK	MALACCA	KEDAH	PERLIS	KELANTAN	TRENGGANU
4,000 GAL - $2.40 4,000 GAL @ $1.10/ GAL	UP TO 2200 GAL - $2.50 FURTHER 4400 GAL @ $1.35/ 1000 GAL FURTHER 5600 GAL @ $1.50/ 1,000 GAL ABOVE 13200 GAL @ $1.64/ 1000 GAL	FIRST 2000 GAL @ $1.00/ 1000 GAL OVER 2000 GAL @ $1.20/ 1000 GAL	$1.00/1000 GAL	$1.00/1000 GAL	$1.50/1000 GAL
- DO -	- DO -	- DO -	- DO -	- DO -	IN EXCESS OF FREE SUPPLY $1.50/1,000 GAL
- DO -	- DO -	- DO -	- DO -	- DO -	- DO -
50/ 1,000 GAL	$1.50/ 1,000 GAL	-	-	-	-
$2.40	$2.50	$1.00	$1.00	$2.00	$1.50
1.70/ 1,000 GAL	UP TO 2200 GAL - $10.00 (MIN) ABOVE 2200 GAL @ $3.00/ 1000 GAL	$2.00/ 1000 GAL	$2.00/1000 GAL	$1.50/1000 GAL (MIN CHARGE $3.00)	$2.00/1000 GAL (MIN CHARGE $4.00)
- DO -	UP TO 2200 GAL - $7.50 (MIN) ABOVE 2200 GAL @ $2.64 1000 GAL	- DO -	- DO -	$1.50/ 1,000 GAL	$2.00/1000 GAL
- DO -	UP TO 2200 GAL - $10.00 (MIN) ABOVE 2200 GAL @ $3.00/ 1,000 GAL	- DO -	- DO -	- DO -	- DO -
[illegible] - $1.70/1000 GAL [illegible] - $1.10/1,000 GAL	UP TO 2200 GAL - $5.00 (MIN) ABOVE 2200 GAL @ $1.82/ 1000 GAL	- DO -	- DO -	-	- DO -
.70/ 1,000 GAL	UP TO 2200 GAL - $10.00 (MIN) ABOVE 2200 GAL @ $3.00/ 1,000 GAL	$2.50/ 1,000 GAL	$2.00/1,000 GAL	-	$2.00/1,000 GAL
$12.00 $18.00 $24.00 3"Φ - $35.00	UP TO 3/4"Φ - $60.00 1"Φ AND ABOVE - ACTUAL COST PLUS 25% MINIMUM - $90.00	$15.00 PER CONNECTION	1"Φ - $12.00 1¼"Φ TO 2"Φ - $18.00 2¼"Φ TO 3"Φ - $24.00 OVER 3"Φ - $36.00	1"Φ - $12.00 1¼"Φ TO 2"Φ - $18.00 2¼"Φ TO 3"Φ - $24.00 OVER 3"Φ - $36.00 (+ 25% OF THE OVERALL COST)	1"Φ - $12.00 1¼"Φ TO 2"Φ - $18.00 2¼"Φ TO 3"Φ - $24.00 OVER 3"Φ - $36.00
-	$10.00	-	$2.50	$2.50	$2.50
-	$2.00	-	$2.50	$2.50	$2.50
$4.00	$3.00	$4.00	$4.00	$4.00	$4.00
-	½"Φ - $0.50 ¾"Φ - $1.00 1"Φ - $2.00 1½"Φ - $3.00 2"Φ - $4.00 4"Φ - $0.00	-	-	SIZE - DOMESTIC - TRADE ½" - $4.00 - $8.00 ¾" - $12.00 - $12.00 1" - $15.00 - $15.00 1½" - $45.00 - $45.00 2" - $50.00 - $50.00 3" - $75.00 - $75.00 4" - $100.00 - $100.00	-
$7.50	¾"Φ AND BELOW - $10.00 EXC ¾"Φ NOT EXC 1½"Φ - $15.00 EXC 1½"Φ NOT EXC 2½"Φ - $20.00 EXC 2½"Φ NOT EXC 4"Φ - $30.00	$7.50	$7.50	$7.50	$7.50
$20.00 $5.00	$20.00 $5.00	$20.00 $5.00	$20.00 $5.00	- -	- -
$25.00 $2.00	$25.00 $25.00	$25.00 $2.00	$25.00 $2.00	$25.00 $2.00	$25.00 $2.00
-	$50.00	-	-	-	-
[illegible] COST PLUS 25% [illegible]HEAD CHARGE	-	ACTUAL COST PLUS 25% OVERHEAD CHARGE	ACTUAL COST PLUS 25% OVERHEAD CHARGE	ACTUAL COST PLUS 25% OVERHEAD CHARGE	ACTUAL COST PLUS 25% OVERHEAD CHARGE

DEC., 1978.

Paper 4c

Water Charges Policy as applied to Penang

by Kam U-Tee, BCE., FIEM., FICE., Deputy Chairman/General Manager, Penang Water Authority

WATER CHARGES POLICY AS APPLIED TO PENANG

Introduction

The State of Penang has an estimated population of 900,000 inhabitants. It comprises the 110 sq. mile Island of Penang and a 282 sq. mile strip of coastland on the West coast of Peninsula Malaya. Most of its urban population reside in the City located on the Island whilst a very fast-growing industrial estate is transforming the previously rural nature of the mainland.

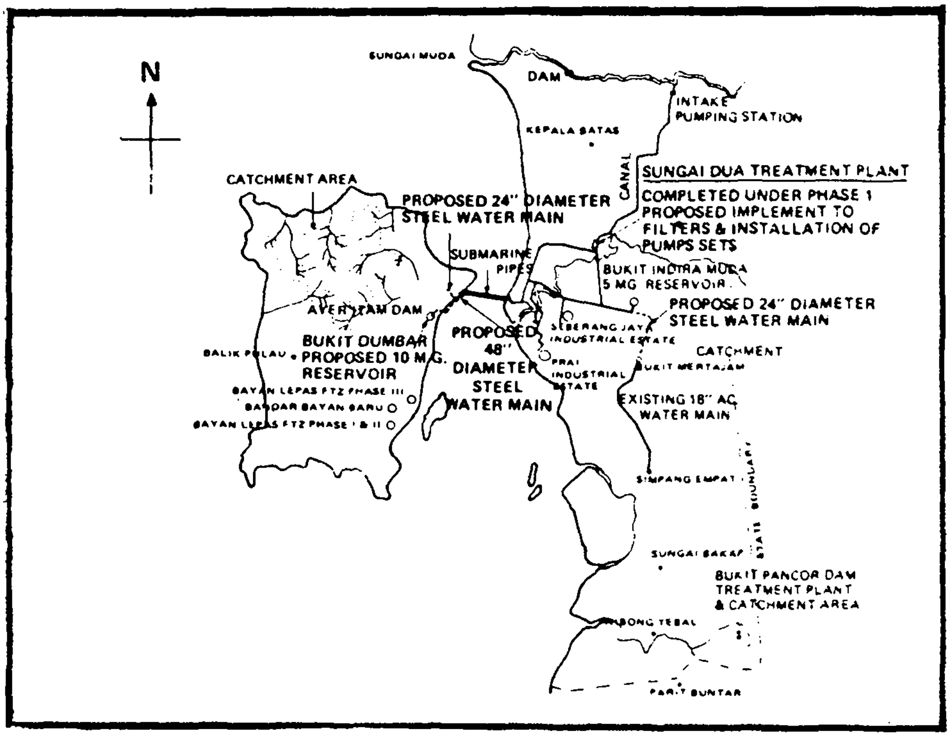

Fig. 1 : Map of Penang Water Supply

The Penang Water Authority was constituted by State Law in 1973. The former City Water Department and the former water supply section of the Public Works Department were thereby integrated into one State-wide water supply undertaking. Supplies now total 54 million gallons per day. There are 91,000 domestic supplies and 6,000 trade supplies. All consumptions are metered - there are no free supplies and unaccounted for losses are kept to 18% of out-put from filtration plants.

Financial policy of the Authority required it to generate sufficient revenue from sales of water to pay for wages, operating costs, loan servicing charges and minor recurrent capital works.

Some idea of this policy may be obtained from inspection of Table 1, a worksheet on water production costs and revenue since 1974.

	1974	1975	1976	1977	1978 (Est.)
1. SALES VALUE	$11,185,770	$12,440,505	$13,690,257	$14,543,807	$15,313,000
2. SALES VOLUME - GAL.	11,877,570,000	13,434,050,000	14,491,870,000	14,900,236,134	16,129,180,000
3. AVERAGE PRICE PER 1,000 GAL.	94¢	92¢	94¢	97¢	95¢
4. COST OF PRODUCTION					
- MANAGEMENT	$1,390,814	$1,764,355	$1,758,114	$1,873,774	$2,310,950
- PRODUCTION	2,644,175	3,344,937	3,440,200	4,084,987	4,631,700
- DISTRIBUTION	1,722,580	1,610,853	1,525,645	1,825,057	2,388,220
- DEPRECIATION	2,491,940	2,656,365	2,767,565	2,829,540	2,850,000
- INTEREST	3,048,855	3,041,008	2,975,089	2,847,079	3,030,010
- ADJUSTMENT	126,766	126,766	(859,818 (126,766	121,451	-
	$11,425,130	$12,544,284	$13,453,197	$13,581,888	$15,210,880
5. COST OF PRODUCTION PER 1,000 GAL.	96¢	93¢	92¢	91¢	94¢
6. MISCELLANEOUS INCOME	338,082	742,988	835,667	561,000	500,000
7. RATE OF RETURN ON TOTAL ASSETS BEFORE CHARGING INTEREST	4.2%	4.9%	5%	5.3%	

Table 1 : Worksheet on Water Production Costs and Revenue

Financial Position Prior to 1973

In 1972, the combined water revenue of the two waterworks absorbed into the Authority amounted to just M$7.5 million a year. A new extension scheme, the Muda River Waterworks Scheme, (1) costing M$40 million was in an advanced stage of construction and loan servicing charges amounting to M$4 million per annum became due after 1973.

Upon inception, the Authority had the immediate job of introducing a new uniform rate of charges. This new rate of charges had at the same time to increase revenue by about 40%.

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(1) The Muda Water Scheme : Water & Water Engineering Nov. 1971 by Foo Fook Foon

Metered Charges versus Rates based on Property Values

One component of the mainland water revenues was derived from a 3% levy on property values of premises located within a given distance from water mains. This tax element served an income distribution function as it would increase the burden of charges in higher valued properties. Nevertheless, it had been eliminated from the Penang Island system of charges. After due deliberations, it was decided not to introduce this element of property tax to the Island but to abolish it altogether from the mainland. In doing this, the Authority had noted that municipalities throughout the world were showing signs of financial stress - they found great difficulty in financing their activities out of revenues derived mainly from property taxes. It was felt that the Water Authority should not add an additional burden on this sector.

Direct user charges imposed on metered supplies are a simple concept. The community pays for the service it gets. Users pay in direct proportion to their consumption. However, in a developing country, criticism has been levelled on direct user charges on the grounds that the lower income earners have to pay a greater burden (relative to their incomes) in order to enjoy the benefits of a piped water supply. This criticism has been given due consideration by the Authority. It is the opinion of the Author that it is inevitable that a higher proportion of the income of poor families should be utilised for the basic necessities of life. Conversely, it is not possible to carry out income distributive policies to a level where essential commodities will be charged against higher income earners in direct proportion to their earnings. A public utility should instead attempt to subsidise prices, or at least a part thereof, to such an extent that the benefits supplied by its facilities may be utilised by all sections of the community. The policies of the Penang Water Authority have been inclined to this doctrine.

Although overall charges for water have been fixed to yield a rate of return on total assets of around 5%, some form of subsidy has been given to the under-privileged. Thus, about M$500,000 a year is earmarked as a 'social dividend' paid to the community in place of dividend to shareholders. This money is used to lay water mains to rural areas which would not otherwise justify the investment of laying the pipes. Again, in order to encourage connections from the houses to the public mains, interest-free loans are given to rural householders. Instalment payments are incorporated in their monthly water bills and periods for payment may be extended beyond three years, if necessary. (2)

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(2) Water Billing & Collection System in Penang: CISEAN CONFERENCE, Kuala Lumpur, Dec. 4, 1978 by Kam U-Tee.

Consistent with this policy, the new domestic charges contain a subsidised element. A two-part domestic tariff was introduced. The first part was to be a subsidised rate meant for essential uses of water. The second part of the domestic tariff was fixed at the 'average cost' of water. Trade charges were fixed at a higher level of costs corresponding to the cost of bringing in new water, the surplus earned on trade charges was used to subsidise the lower domestic tariff. Tables II and III list out the water charges pertaining to the earlier water undertakings and the final water charges applied in 1973.

Purpose	City Water Dept. M$/1000 gal.		Public Works Dept. M$/1000 gal.
Domestic	Urban	Rural	
Minimum charge	1.00	1.00)	
First 10,000 gal/mon	0.50	0.60)	
Next 20,000 gal/mon	0.55	0.60) -	0.60
Next 20,000 gal/mon	0.65	0.80)	
Over 50,000 gal/mon	0.80	0.99)	
Domestic and Trade	Same as domestic		0.80
Trade	Same as domestic		1.00
Hotels, Restaurants, Public Entertainment	1.20		Same as Trade
Contractors Services; Ice and Aerated Water factories	2.00		1.25
Sampan Staging	2.00		1.75
Harbour Shipping	3.00		3.00

Table II : Water Charges Prior to 1973

Purpose	Rate (M$/1000 gal.)
Domestic	
Minimum charge	2.00 per mon.
First 5,000 gal/mon	0.60
Over 5,000 gal/mon	0.95
Trade	
Ordinary:	
First 5,000,000 gal/mon	1.30
Next 5,000,000 gal/mon	1.10
Next 30,000,000 gal/mon	0.90
Over 40,000,000 gal/mon	0.80
Contractors' services; Ice and mineral water factories; Sampan staging	2.00
Harbor shipping	3.00
Minimum trade charge	5.00 per mon.

Table III : Water Charges after 1973

Trade Charges

In 1973, Penang was embarking on an ambitious industrialisation programme. Although it had been decided to subsidise domestic consumption out of revenues generated from trade charges, the level of charges should not be so high that they would inhibit the setting up of industries. Examination of this constraint indicated that several thousand Ringgits worth of consumption would in most cases form an insignificant part of costs of a commercial business. The limits here would not be 'what the market will take' but the level of charges in neighbouring states. Beyond several thousand Ringgits a month, some form of encouragement to industrialists was deemed appropriate. A unique system of declining charges was introduced to Penang. Care was still exercised to ensure that the average charges at high levels of consumption would still be above the average cost of water. Inspection of 1972 consumption figures indicated that an expectation of 18% consumption sold at Trade rates was reasonable.

Domestic Consumption

In order to make meaningful concessions to domestic tariffs, some insight into the consumption pattern of consumers was necessary. In 1972, while the Author was City Water Engineer, assistance from the School of Social Sciences, Universiti Sains Malaysia, was obtained to carry out a survey in anticipation of this problem. The survey was organised by Dr. Donald Blake and a team of undergraduates who undertook to interview consumers and fill in a questionnaire pertaining to user statistics in Penang Island. All together, a representative sample of 5% of the metered population was selected from the Department's meter books. Questions asked sought information on number of people residing at the premises, number of water fittings, water closets, number of cars and whether or not there was a lawn. In anticipation of resentment to direct questions about incomes, it was decided to classify incomes into four groups, those whose household incomes were below M$150/- per month, those whose household incomes were between M$151/- and M$500/-, "middle income" households with earnings between M$501/- and M$800/- per month and "higher" income households with incomes above M$800/- per month. About 80% of questionnaires were answered - data on about 1,500 houses were compiled. Apart from the larger sampling, a more intensive sampling was chosen from 6 typical housing areas. In these areas, a 20% coverage was achieved. The 6 types of housing represented were a rural fishing village; an urban squatter settlement; a high quality residential neighbourhood; a middle quality housing estate; town houses comprising terrace houses on the fringe of the City; and finally, shop houses in the City proper. As anticipated, no useful returns were obtained regarding incomes from shop houses - cooperation in other spheres was good and some parameters of this intensive study are tabulated in Table IV.

	DESCRIPTION	AVERAGES				CONSUMPTION PROFILE (No. Of Houses Consuming X)					POPULATION PROFILE (No. Of Houses having X People)					INCOME PROFILE (No. of Houses having $X Income)			
		No. of Houses	Av. Monthly Consumption	No. of People Per House	Av. Consumption per cap. per day	30,000+	15,000 → 30,000	10,000 → 15,000	5,000 → 10,000	0 → 5,000	0 → 5	6 → 10	11 → 15	16 → 20	21+	150 -	151 → 500	501 → 800	800 +
A	Fishing Village	50	6.25	7.04	29.5	0	1	7	21	21	16	28	5	1	0	18	21	2	2
B	Squatter Slum	52	6.50	8.46	25.8	0	2	6	28	16	12	31	8	0	1	27	18	0	0
C	Detached Bungalows	38	15.7	5.44	96.2	3	15	12	7	1	20	16	2	0	0	0	0	0	38
D	Housing Estate	56	8.6	5.66	51.1	0	3	9	33	11	30	23	2	1	0	0	16	19	18
E	Shop Houses (City)	98	15.1	10.3	48.8	3	39	36	16	4	19	38	25	13	3	No figures			
F	Town Houses (City fringe)	51	11.6	8.78	43.9	1	10	16	21	3	13	21	15	1	1	3	31	11	4
	Total	345	11.0	8.0	45.7	7	70	86	126	56	110	157	57	16	5	←→			
	Adjusted Total	395	10.4	7.9	43.7	7	71	93	147	77	126	185	62	17	5	←→			
	%					1.7	18.0	23.5	37.3	19.5	31.9	46.8	15.7	4.3	1.3	←→			

Table IV : Penang Water Supply - Survey of Social Factors & Water Uses

Some interesting statistics may be derived from the above tabulation. The average number of people per household was 7.8. Daily per capita consumption varied from 30 gallons per head per day through 45/50 gallons per head per day for middle income households to nearly 100 gallons per head per day for high quality houses. Average household consumptions of 6.5 units per month in the fishing village and the squatter settlement reflected low per capita consumptions coupled with lower family sizes of between 7 to 8 people per house (single tenancy). Town houses and shop houses reflect moderate per capita consumptions but multiple tenancies in shop house areas inclusive of many common lodging houses have pushed average monthly consumptions to 15 units per month. Although the size of families in high quality houses is between 5 and 6 persons, average monthly consumptions above 15 units are returned.

Results of this study are extrapolated to other areas by comparing monthly average consumptions in the different zones. (See Table V).

	Consumption in units of 1000 gallons			
	Av. Monthly Consumption per domestic premises		Total Domestic Monthly Consumption	
	1972	1978	1972	1978
Mainland : Central	7.68	)	42,996	
: North	8.66	) 9.60	87,192	
: South	5.95	)	20,894	
Mainland : Total	7.87	9.60	151,100	324,660
Island : District	7.69		131,800	
Island : City	14.66		337,000	
Island : Total	11.83	10.20	468,800	575,090
Total System	10.5	9.95	619,900	899,750

Table V : Penang Water Supply - Analysis of Domestic Consumption

It was concluded that a cut-off point of around 5,000 gallons per month for the subsidised domestic tariff would provide useful subsidies to single tenancy low income housing such as the squatter settlement and the fishing village.

Multiple tenancies in the City would not benefit considerably from the subsidised tariff. However, the loss of subsidy per family would not amount to more than M$1.75 per month. Considering these sub-tenants do not pay directly for services but are charged room rentals instead, the loss of subsidy would not be directly felt.

Calculation for Total Average Prices

Domestic consumption in the previous City water supplies was charged at a sliding scale. Analysis of these different categories of charges was available. These are indicated in Table VI.

PENANG ISLAND METERED CONSUMPTIONS 1972 (OCTOBER)

	DOMESTIC SUPPLIES						TRADE SUPPLIES						TOTAL SUPPLIES
	0 TO 2,000	2,001 TO 10,000	10,001 TO 30,000	30,001 TO 50,000	50,000 +	SUM	HOTELS	BUILDINGS	GOVT.	C COUNCIL	SHIPPING	SUM	
CITY	53,606 (15.9)	156,210 (46.3)	92,939 (27.6)	13,474 (4.0)	20,800 (6.2)	337,029 (100)	17,330	1,118	24,862	18,761	3,641	65,712	402,741
DISTRICT C	36,081 (27.4)	71,346 (54.1)	19,065 (14.5)	1,929 (1.5)	3,451 (2.6)	131,872 (100)	1,816	3,572	7,920	1,501	0	14,809	146,681
TOTAL (ISLAND)	89,687 (16.3)	227,556 (41.4)	112,004 (20.4)	15,403 (2.8)	24,251 (4.4)	468,901 (85.3)	19,146 (3.5)	4,690 (0.9)	32,782 (6.0)	20,262 (3.7)	3,641 (0.7)	80,521 (14.7)	549,422 (100)

MAINLAND METERED CONSUMPTIONS 1972 (JANUARY)

	DOMESTIC	DOM / TRADE	STAND PIPES	SUM	TRADE	TRADE SUPPLIES TRADE SPECIAL	SHIPPING	SUM	TOTAL SUPPLIES
MAINLAND (N)	87,192 (55.6)	14,519 (9.3)	4,811 (3.1)	106,522 (67.9)	42,559 (27.1)	5,863 (3.7)	1,876 (1.2)	50,298 (32.0)	156,820
MAINLAND (C)	42,996 (68.0)	7,306 (11.6)	3,626 (9.7)	53,928 (85.3)	7,693 (12.2)	1,625 (2.6)	0	9,318 (14.7)	63,246
MAINLAND (S)	20,894 (65.6)	3,817 (12.0)	4,108 (12.9)	28,819 (90.5)	2,736 (8.6)	282 (0.9)	0	3,018 (9.5)	31,837
TOTAL (MAINLAND)	151,082 (60.0)	25,642 (10.2)	12,545 (5.0)	189,269 (75.1)	52,988 (21.0)	7,770 (3.1)	1,876 (0.7)	62,634 (24.9)	251,903

	DOMESTIC	TRADE	SUM
TOTAL ISLAND	468,901	80,521	549,422
TOTAL MAINLAND	189,269	62,634	251,903
TOTAL STATE	658,170 (82.1)	143,155 (17.9)	801,325 (100)

NOTE: UNLESS OTHERWISE STATED FIGURES ARE FOR CONSUMPTION IN UNITS OF 1000 GALLONS

PERCENTAGE FIGURES ARE WITHIN BRACKETS

Table VI : Analysis of Diffferent Categories of Charges

From these tables, cumulative distribution curves can be prepared (see Figure 2).

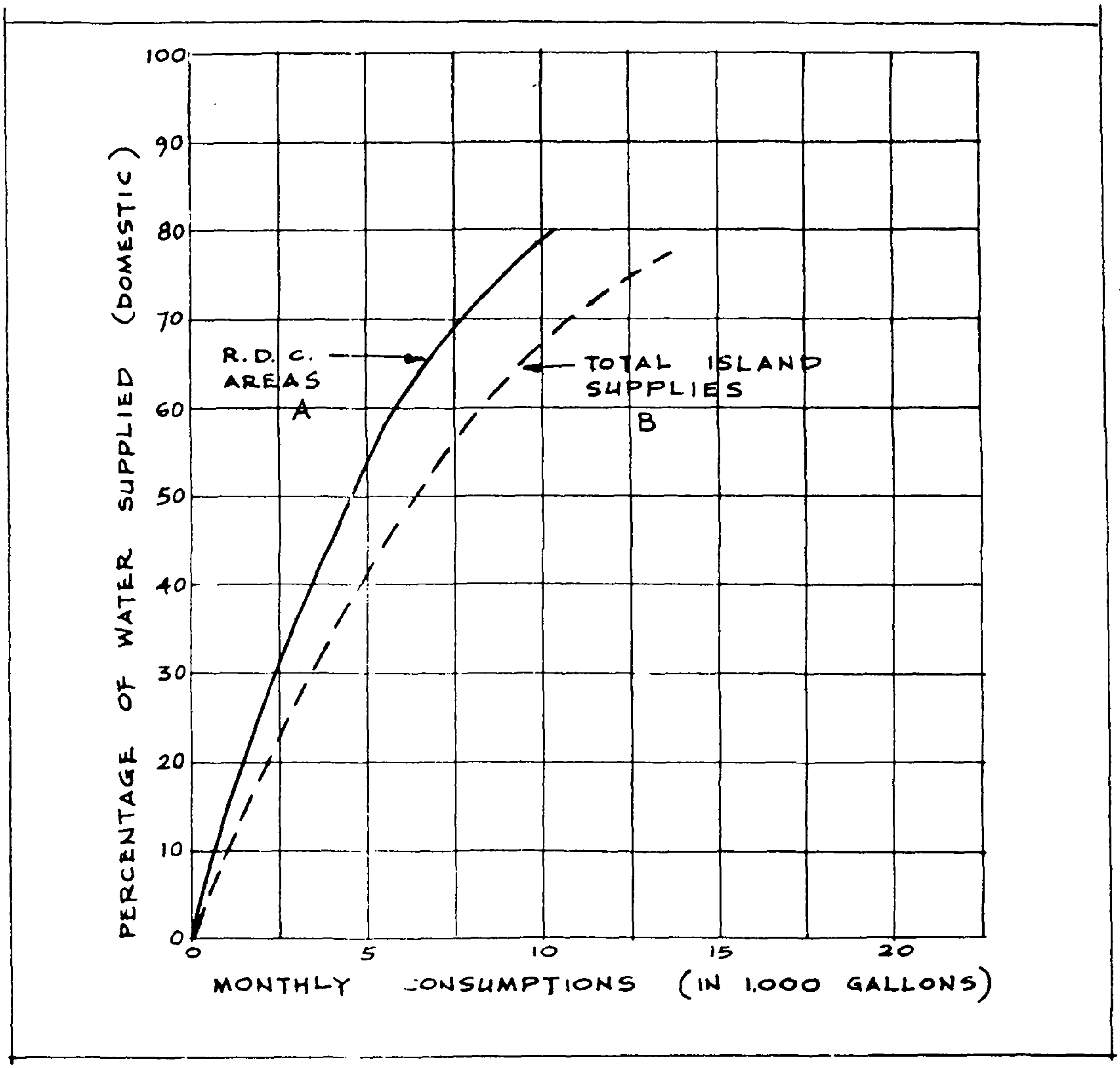

Fig. 2 : Cumulative Distribution Curve
Percentage of Domestic Supplies Sold
Under A Given Monthly Consumption

Statistics in the former City Water Supplies can be divided into the Rural District Council areas (mainly rural with scattered urban suburbs) and the City Council areas. Two cumulative distribution curves A and B have been prepared in Figure 2. Examination of Table V suggests distribution curves for the total mainland areas and the Rural District Council areas of the Island are similar. Total domestic consumptions for the mainland areas and the Rural District Council areas when added together will approach the magnitude of domestic consumptions in the City areas.

The total Cumulative Distribution curve for the whole State is assumed to lie half way between curves A and curves B in Figure 2. From this, at a cut-off point of 5,000 gallons per month, 46% to 48% of domestic consumption would be charged at the lower subsidised rate. Average domestic charges would be 78¢ and with a trade ratio of 18% average sale price is now estimated at 87.5¢ per unit.

Sensitivity Analysis

The above estimates have been arrived at by a "straddling the target" technique. Upper and lower limits of certain parameters have been defined, the correct answers lie somewhere between these limits. It becomes necessary to test the sensitivity of these limits. Accordingly, a sensitivity chart relating total average price to average domestic price and percentage of trade sales was constructed and is represented in Figure 3.

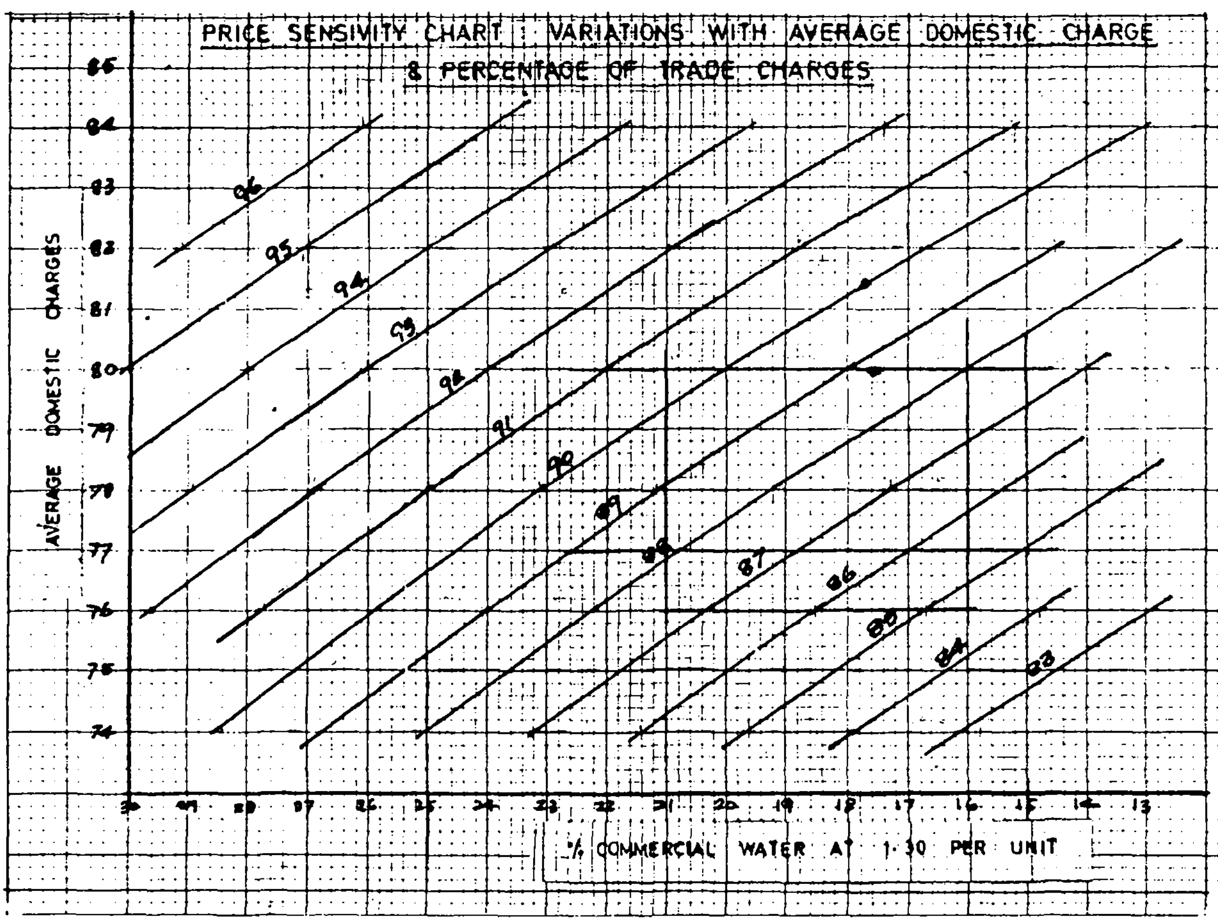

Fig. 3 : Price Sensitivity Chart

Domestic prices may vary between 76¢ and 80¢ per unit. On the other hand, percentage of trade consumptions may vary between 16% and 20%. From these ranges and Figure 3, an average target price of 87.5¢ is obtained with a possible variation of ± 3¢.

Price Elasticity Factor

Up to this point, it has been assumed that increased charges do not result in decreased consumption. Hanke (3) has defined a mathematical model for price elasticity of water. This is given by the relationship:-

$$Q = aP^{b}$$

where Q = Quantity of Demand; P = Price;

b = price elasticity coefficient; a = constant

b has been listed to vary between 0 to -0.3.

Assuming an average family consuming 7 or 8 units of water per month at a price of M$1.00 per unit. price elasticity curves have been plotted for values of b of -0.1; -0.2 and -0.3 respectively. (These curves look entirely different from the straight line models drawn by economists which suggest that demand tends to zero when prices are still a finite value). (See Figure 4).

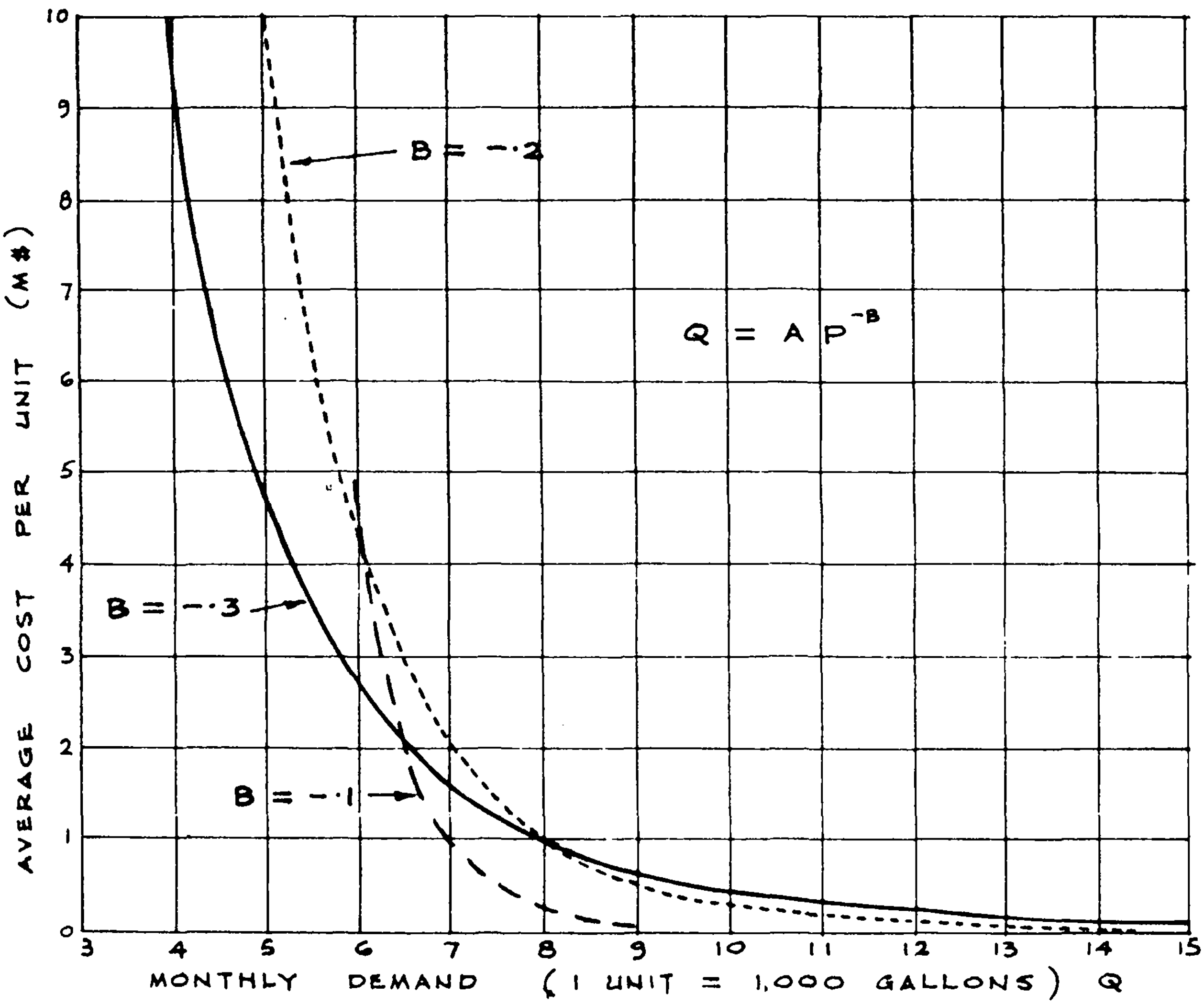

Fig. 4 : Price Elasticity Chart

(3) Method for Integrating Engineering & Economic Planning, AWWA Journal Sept. 1978 by Steven Hanke

Observations in Penang indicate that when cost is zero, as in labour lines and hotels, per capita consumption doubles from 45 gals./day to 90 gals./day. Again, during a recent drought in another city, shortages occurred and water was known to be sold at M$2/- per 5 gallon kerosene tin (equivalent to M$400/- per unit). These two observations suggest a price elasticity of -0.2 for Penang. Using the relevant curve and allowing a price change from 65¢ to 78¢ per unit, a drop in consumption of about 4% may be calculated. Since this figure is of the same magnitude as the annual increase in demand of Penang Island, no serious inaccuracies would have resulted by the original assumption of zero price elasticity.

Results Reviewed after 5 Years

At the time that calculations were first made in 1973, trade component of consumption was only 21% in the mainland. This had increased to 25% by December of 1973. It continued to grow to 32% in 1974, 41% in 1975 and has stabilised at 44% in 1977 and 1978. In Penang Island itself, trade component of consumptions increased from 18% in 1973 to 23% in 1978. As a consequence, unit price of water averaged 90¢ in 1973 and has now increased to 95¢. At this average sale price, 31% of all sales is charged at Trade rates and this accounts for 42% of water revenue.

Average unit price of domestic sales has increased from 79¢ to 80¢ during this period. These results testify to the accuracy of the 'straddle' technique.

Conclusions

In conclusion, the objectives set up by the Water Authority with its new water charges have been achieved. These are:-

(1) Selling price of water has been raised from 65¢ to 95¢. The financial position of the Authority has been safeguarded.

(2) The methods used to arrive at the estimated sale price for water, even though they are based on partial data available, have been reasonably accurate. Initial accuracy of 3% was achieved.

(3) Although trade charges have been used to subsidise domestic charges, no inhibition of the industrialisation programme has been noticed. Proportion of total consumption charged at Trade rates has increased from 20% to 31%.

(4) An average-sized family of 8 with per capita consumption of 25 gallons per head per day would return a monthly consumption of 6,000 gallons. Most of this water would be consumed at the subsidised domestic rate. This would encourage participation of a low income family.

(5) There remains only the criticism that no significant subsidy has been made available to large urban families staying in common lodging houses. The Authority is currently examining procedures to register the occupants of these lodging houses so that a larger bloc of subsidised tariffs can be made available to them.

(6) Provided the above measures have been implemented, it would be possible to introduce a third tariff bloc to domestic consumption. The object of this tariff would be to suppress excessive consumption. Charges for consumption say above 15,000 gallons per month could be levied at M$1.30 per month, i.e. at the same level as industrial tariffs.

To sum up, although no property taxes have been incorporated in the water prices in Penang, an efficient and yet equitable policy of charging its consumers has been arrived at.

List of Tables and Figures

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Paper 4d

The Problems of Water Meters and Metering in Indonesia

by The Indonesian Water Supply Association "Perpamsi"

Good water meters are essential in the operation and management of water works.

The problems of water meters and metering in Indonesia have been realized only recently after many years of neglect. Actual water consumption is recerded by estimation based on certain assumtion, which is a common practice of measuring water consumtion when meters are out of order. Efforts to improve metering practices have been discussed in the Water Works Convention in 1978 The following is a brief description of the problems on the provision of water meters and metering in Indonesia which hopefully will give the readers better insight of the situation confronting the Indonesian water works.

EARLY CONDITION AND PRESENT DEVELOPMENT

Historically, drinking water systems in Indonesia were first introduced by the Dutch in early 1900's. Public water systems were mostly built in cities where many Dutch population resided. These cities are mostly located in the island of Java. At that time the supply of drinking water for domestic purposes was distinguished between the Europeans, the Asian ethnic groups, and the natives through different water standards. Urban population were served by means of house connections, yard connections, and public taps. All connections were metered.

During the Dutch administration, most of the water works operated continously for 24 hours a day. After WW II, however, due to various problems, many of the old systems began to work intermittently, sometimes only a few hours a day.

Construction of new water systems or even for that matter extention or rehabilitation of the existing systems were not undertaken because of financial reason and other priorities. Lack of maintenance and rehabilitation have caused the existing systems to deteriorate. The original production has decreased due to incrustation of pipes. Leaks estimated at 40-60% of the total production were a common situation. Many of the meters were out of order and only few replacements were made due to lack of funds. The problem was further aggravated as the demand increase due to the growth in urban population. Today it is estimated that about 20% (26 million) of the total population live in urban areas comprising about 330 cities and townships. Only 33% of the urban population is served by public water systems.

Beginning with the 1st Five Year Plan (Pelita I) in 1969 the Government began to undertake development in all sectors. At that time water works development was not given proper attention. Top priorities were given to economic sectors. Only cities with economic potential were given serius consideration. In the 2nd Five Year Plan (Pelita II) however more emphasis was given to water supply projects extending to medium and small size cities (secondary urban centres). The Government plans to increase the original total production of about 8.000 l/s to 27.000 l/s by 1979 in strengthening urban facilities within the framework of regional autonomy and urban growth centre. By the end of this century it is expected about 70% of the future urban population will be served by the public water systems.

Prior to 1969 the management of water works were carried out by the municipality, commonly known as Water Works Service which was actually an administrative arm of the municipality. Water revenue was handled by the Municipal Revenue Service; whereas, annual budget was prepared by the Water Works Service. This arrangement was considered inefficient in providing good services to the public.

The Government therefore has initiated to established a separate and independent entity for the local water works. In Pelita I 54 water supply projects were in fact undertaken. By 1978, 127 water supply studies of secondary urban centres had been completed. Projects undertaken are financed through government's equity, loans or subsidies. In support of Government's efforts local water works throughout Indonesia then joint themsevs to form an Association whose function among others is to improve the management and operation of water works enterprises, and also to promote water industries. The Association shares the responsibility of providing good public services of continous supply of drinking water. One of the many concerns to the Association is the problems of water meters and metering.

PROBLEMS

Meter problems in Indonesia are mainly due to financial constraints and institutional enefficiency. Due to lack of funds no rehabilitation works or extention of the existing systems including water meters replacements are carried out by the water works enterprises. The supply of pipes, water works equipments and materials are met through import from various foreign manufacturers,
However, pipe factories such as asbestos cement and pvc pipes are now available locally. Water meters are still purchased by importation through compatitive biddings giving a wide opportunity for many meter manufacturers to market their products in Indonesia. The adoption of competitive biddings imposed certain problem in the supply of water meters. Presently there can be found about 40 different brahds of water meters being used by the water works enterprises throughout Indonesia. Long and time consuming procedures for the provision of meters caused delays in the replacement programs of worn out meters.

Meters spare parts cannot be maintained continously for the same reason. In purchasing the meters the local water works enterprise does not impose any standards which can eliminate those meters not technically suitable.

The situation is quite different in the case of water supply projects undertaken by the Government. Purchase of imported materials or goods must satisfied the required specifications. From past experiences it was knowns that certain type of meters are not efficient. The Government therefore set a standard for house connection meter by specifying accuracy, dry dial magnetic type, minimum and maximum flow rate, etc. This standard has not yet been widely accepted by the local water works enterprises, and it only specifies the minimum requirements.
Nevetheless, it has succeeded in limiting the number of water meters available in the markets that meet the standard into 4 different brand.

The supply of meters from various manufacturers caused problems in meter connection or replacement of different brand. Certain adoptor or meter coupling must be used for replacing the old meter with new meter of different brand because of different body's dimension.

Not all of the water works enterprises today own general maintenance shop enabling to repair and test the meters. Large water works enterprises however are equipped with good facilities. Meter maintenance program is difficult to carry out because of the problem mentioned before. Meter replacement is supposed to be executed for certain period depending on the life time of the meter in service 3,4 or 5 years. Meter which undergo servicing are given new seals before being put back into operation. Lack of spare parts sometimes force the water works to utilize spare parts of other different meters. Furtheremore worn out meters are not depreaciated accordingly. Worn out meters are still considered in service until being replaced with new ones. For the sake of water billings, meter readings are done by estimating the consumption of the previous month.

Lack of skilled technicians for meter maintenance and repair also become the concern of the Association. Training programs for water works operations and technicians are regularly carried out by the Government. Training program on meter maintenance and repair however is conducted by the water works enterprises.

A decrease in the supply of water to the consumers over many years caused the meters to deteriorate more quickly. Worn out meter components before its life time are very common. Meters installed at the public taps wore out faster due to excessive consumption. Physical leakge due to old pipes or unaccounted for water such as illegal connection or meter hampering or wastage is part of both technical ans social problems in addition to administrative leakges.

RECOMENDATIONS

Improvements in water works management through a sound water meter program should be carried out in a coordinative manner taking technical, financial and social aspects into consideration. Some of the measures recommended are as follows:

1. Water meter standards which is suitable for the tropical condition should be adopted and endorsed by the Government, through a revised procedures in the provision of imported meters. This measure is intended to reduce the number of meter of different kinds presently available in the market.
2. A sound public information program to increase public participation and awarness in becoming a good customer should also be carried out.
3. Training program for water works opetators and technicians should be conducted regularly.

4. In order to maintain continous supply of water meters, it would be worthwhile to consider the establishment of meter factories/manufacturers in Indonesia.
5. Leakge control program and augmentation of the present production should also become the concern of both the Government and the local water works enterprises.

Paper 5a

Conference 5th Session, Wednesday, 14th February— The Training of Managers and Men

Introduction

This short paper aims to set the scene for a discussion of problems encountered in expanding and maintaining water supply systems, and of some possible solutions which can be provided through training. It is expected that various speakers will offer formal papers, or informal comments during the session at the Conference, from which may be gathered valuable accounts of experience, opinion, judgement and available expertise and knowledge, enabling delegates to add to and take from what has already been discovered in other countries.

Set down below is a range of headings which attempt to collect together some of the major problem areas, and into which delegates may find it useful to direct their contributions.

Policy

In order to have an effective water supply system, there needs to be an overriding policy set by as influencial body as possible. This body could frequently be government, will perhaps sometimes be the state or region within a country, and often will be the local water authority. Basic training and education provision is probably therefore required to ensure that the policy-setting body understands the economics of providing a water supply, makes arrangements for an assessment of water resources and likely demand, and teaches the consumer to understand the problems of maintaining a water supply, including those of cost and hygiene.

Water Resources

Realistic information on the national water resources is frequently not available. An investigation into the ground and surface water situation is quite fundamental, and the training of staff to plan and design and then to supervise projects which will produce data on which to base extensions to existing systems and complete new systems is a considerable task.

Existing Systems

Leakage from many existing systems is at such a high rate that planned new source works may frequently be delayed by reducing waste, the financial savings accruing being quite enormous. The correct installation of pipework and the techniques of leak detection and control are quite simple and easily taught, and a small investment in very basic training has been shown to pay large dividends.

Maintenance of Systems

Adequate maintenance of the existing water system is probably the most difficult to achieve of all operations in the water service. The training of staff to carry out routine maintenance is straightforward and swift. However, close attention should be paid at the design stage to simplicity and standardisation, so that the skills of anticipating, recognising and rectifying faults in the system, traditionally difficult to inculcate, may be more readily acquired. Particularly in rural communities installations that are secure, simple and robust and able to withstand abuse are valuable since they minimise maintenance and repair problems.

General Technical Expertise

The design, installation, operation, control and maintenance of water systems call for technical expertise of a variety of sorts, coupled with an overall understanding and ability vested in one or two key people. Where new systems are being created it is common to buy in from elsewhere expertise usually in design and installation. However, to rely on continued outside assistance in operation, control and maintenance is unwise and frequently impossible. It is therefore quite vital to ensure from the earliest possible stages that a small nucleus of well-trained and preferably experienced staff are available, on which to rest firm foundations for an efficient and lasting system and organisation.

Manpower

An assessment of manpower needs, preferably made at design stage is quite essential. The location of a few well-trained staff in key positions is of vital importance, and the chance of arranging for such staff to "grow up" with the system from design to implementation has so many advantages. However, in poorly staffed organisations, experts frequently achieve transfer to administrative jobs, and their expertise is diluted by infrequent use.

Style and Type of Training - Commitment

Training can take place anywhere and in many disguises. It should not be assumed that training must be formal and sophisticated, since the best training is generally on-the-job at the hands of an experienced person who has the gift of communication. Therefore efficient training relies equally on staff motivated to learn, and on committed and able trainers whether they be trained trainers or technical experts. The larger the network of training involvement available the better, so that expertise may be drawn from wherever it lies, but an advanced and elaborate training system is only as good as those people committed to and involved in it. As with the water system, so with the training system - it has to be understood and maintained, and should provide precisely what is required.

Training Solutions

It is unlikely that any problems in water supply can be solved just by training. Almost invariably the problems will have technical connotations. Further, where training is seen to be a part-solution, there could well be a variety of ways of providing the training, and the ready-made solution of sending someone on a course run by a third-party frequently does not provide the best answer. The widely held belief that "training is best done by someone else in another place" is generally disproved by experience. A way of encouraging managers and supervisors to recognise their problems, and to attempt to define training solutions involving themselves should be found.

Partnership

The few points set out above do not assume to have covered anything other than a general statement leading to a final simply stated, but difficult to achieve, goal. Detailed considerations such as finance, legal systems and health and safety have deliberately not been mentioned.

Our goal should therefore be "to achieve a partnership of concern and then action between experienced and less experienced nations". Water knows no barriers and the problems of training a capable staff are basically the same everywhere.

Conclusion

It is therefore to be hoped that discussion at the Conference will highlight both problems and solutions through training, so that experience may be shared and existing agencies may be better able to offer their assistance when, where and how it is best applied.

Paper 5b

Training of Managers and Men in Operation and Maintenance of Public Water Supplies

H. Haga, Colombo Plan Expert, Japan International Cooperation Agency

1. Introduction

The main subject of this paper is the Training of Managers and Men in Operation and Maintenance of Public Water Supplies. The Author, however, works in Metropolitan Water Works Authority (MWWA), Bangkok, Thailand under Colombo Plan Expert so that the subject will be mentioned about the background of the plan, design and construction and how to consider adoption of new technique and how to prepare the direction of training under present situation of MWWA.

2. Metropolitan Water Works Authority Bangkok Thailand

2.1 Existing Facilities

Metropolitan Water Works Authority (MWWA) was established in 1967 as a state enterprise under the Ministry of Interior. MWWA is responsible for water supply in Bangkok Metropolis and the provinces of Nonthaburi and Samut Prakarn. Today, its total responsible area is about 3,100 square kilometers, and its service area is about 242 square kilometers, serving the population of 2.6 millions.

MWWA has the Thonburi Treatment Plant and Samsen Treatment Plant which depend on the Chao Phya River. About 660,000 and 190,000 cubic meters of treated water are produced in a day respectively. Two plants are supplemented by additional 350,000 cubic meters per day from deep wells for a total production of 1.2 million cubic meters per day.

2.2 Organization and Staffing

Under leadership of the General Manager and other three Deputy General Managers who assist him in response of the corresponding main line functions.

Deputy General Manager for Engineering - Manages all engineering technical development of the Authority including staff training, responsible for all technical functions to cope with the growing needs of potable water of the communities.

Deputy General Manager for Administration and Finance - Manages all administrative and financial functions of the Authority including revenue collections and service development Responsible in supporting the necessary service to overall work functions in order that the main objective of MWWA is maintained.

Deputy General Manager for Operation - Manages all operating activities of MWWA concerned with the supply, treatment distribution and metering of water, responsible for assuring an adequate supply of properly metered potable water at all times and that the operating facilities are utilized efficiently and well maintained.

There were 5,453 regular employees at the end of 1975.

2.3 Present Training

2.3.1 Training each sessions

10 orientation sessions for 248 newly hired employees. 6 administration sessions for 178 employees. 35 and 25 employees were sent for training at out-side institutions for management and technical courses. 32 fellowships in training and studying abroad for employees were arranged.

2.3.2 Training courses for water works by JICA

There are group and individual training courses for water works by JICA (Japan International Cooperation Agency). These training courses are very limitted in the number of the trainees, so a few persons have had training programmes. To provide experienced engineers working in the water works in developing countries and with up-to-date knowledge of engineering and skills of Japan's water works, these training programmes must be prepared more than present number of the trainees by JICA.

3. The Need of Training in the Background for Water Works

Bangkok has faced the problems of water shortage for many years because the construction of additional water production and supply facilities has not kept pace with the demands of the rapidly increasing population and growing of the city.

As a result, in 1966 the government appointed a committee to study the problems. The U.S. consultanting firm of camp. Dresser & Mckee was selected by the committee in December, 1968.

Camp. Dresser & Mckee performed the study in preparing a Master Plan for water supply and distribution and finished it in February, 1970. The contents of master plan include estimates of population and water requirements up to the design year of 2000. The water supply, treatment and distribution facilities necessary to meet the expected water requirements are described and estimates of the cost of these facilities are presented. The Master Plan also presents recommendations for the operation, maintenance, administration and financing of the proposed facilities.

According to the Master Plan, by the design year 2000, 5,482,000 cubic meter per day of treated water will be served to 8,512,000 people in the Central Water System. A new treatment plant at Bang Khen is recommended to be constructed in stages and completed by then in addition to the two existing plants, Thonburi and Samsen.

Treated water from this new plant will be transmitted through pressure tunnels to several reservoir pump stations located at various centers of water demand through the Central System area.

The Master Plan emphasizes particularly to the Central System area. However, facilities recommendations are also presented to satisfy the requirements in the Separate Water System. In September 1971, MWWA requested the Japanese Government for technical cooperation in the detail design of the Separate System. The Japanese Government examined the Master Plan and recommended that an entirely new feasibility study of the Separate System should be taken. The study was undertaken by many Japanese experts and the Final Report of the Feasibility study was submitted to the Authority in November 1978.

The construction of the additional water supply facilities has commenced in October 1975 as the Phase-1, Stage-1 project. Works include raw water improvement facilities, treatment plant, transmission tunnels, reservoir-pump stations, trunk mains and distribution pipe lines. This Phase-1 Project is scheduled to be completed by midst of 1979 several years delayed from the Master Plan Schedule.

On the other hand, the feasibility study for the Separate System is going on and the Phase-1 Project is now under construction, the Authority realized the present changes of the growing of various communities in the Central area from the time the Master Plan was prepared. The Authority then in 1977 requested the Japanese Government to support experts to review the transmission system and a team for the mission has commenced the work in October.

4. Introduction of Control System

4.1 As the background just mentioned, the schedule of initial plan is behind several years. During the past few years, the project cost increased due to the oil crisis and world wide inflation. During this time, instrumentation and technology for water works rapidly advanced, particularly there have been complete changes in the control systems with the use of the computer, the progress in transmission techniques and the consolidation of comprehensive water supply.

The project is designed with new civil engineering facilities but as for instrumentation more study is required. Therefore, if up-to-date instrumentations would be adopted in the MWWA plan, the quality control, safe operation, labor saving can be well expected.

However, it must be studied what the purpose instrumentation in water facilities is. Especially, it will be better to consider the following items in this case.

(1) Central and local systems for monitoring, control and operation

(2) Transmission between the center and local site

(3) Man machine system at the center, such as the supervisory panel and operating console

4.2 Training for instrumentation

(1) Industrial instrument

a. General .... 5 days

b. System .... 5 days

c. Instrumentation .... 5 days

(2) Telemeter and telecontrol equipment

a. Principle .... 1 day

b. Operation .... 2 days

(3) Computer

a. Hardware

i) Central processing unit ... 5 days

ii) Site instrument .... 3 days

iii) Process input-output unit.. 2 days

b. Hardware (water treatment application)

i) Central processing unit ... 5 days

ii) Site instrument .... 4 days

iii) Process input-output ...... 3 days

c. Software (basic training)

i) FORTRAN .... 6 days

ii) Assembling .... 3 days

iii) COBOL .... 7 days

iv) Monitoring .... 7 days

d. Software (application)

i) System programming .... 3 days

ii) Training of operation ..... 2 days

iii) Training of maintenance ... 2 days

(4) General Operation & Trial Run ..... 20 days

Total: 90 days

5. Conclusion

5.1 The manager for water supply is required to have enough knowledge and experiences on the following items.

(1) Water works management and water charge

(2) Labor and management problems

(3) Water quality

(4) Finance

(5) Water resource

(6) Introduction of new techniques

5.2 Training for technical requirement

5.2.1 Training means learning of present techniques and getting of new techniques, but the willingness to serve is most important.

5.2.2 At the introduction of new technique, we must study it in advance from various sides and it is important to decide what section is to be in charge of handling it when it is completed.

5.2.3 The introduction of new techniques such as systematic control must be planned step by step in cope with the present situation of accepting country. It will be better to avoid the hasty introduction of an unique system of one country, but comparison of various systems is essential.

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Paper 6a

Environmental Implications of a Dam and a Man-made Lake for Drinking Water Supply Warragamba, New South Wales, Australia

by Hans Bandler, Design Engineer,
Metropolitan Water, Sewerage and Drainage Board, Sydney, Australia

This paper deals with the environmental implications of a dam and man-made lake for drinking water supply. The Metropolitan Water, Sewerage and Drainage Board (M.W.S. & D.B.) operates the water supply system in the Sydney (Australia) area which includes Warragamba Dam and Lake Burragorang examined in this paper.

The statements in this paper are not necessarily those of the Board, but are the opinions of the author.

1. Synopsis.

Sydney is the largest and oldest city of Australia.

Water is supplied for Sydney and the South Coast to a population of over three million people.

Warragamba Dam, constructed 1950 to 1960, is the most significant storage reservoir in this system.

The creation of the man-made Lake Burragorang caused loss of farming land, the disappearance of a relic of Aboriginal culture and necessitated relocation of the community living in the valley.

The village established to house the work force for construction of the Dam survived after termination of construction with the introduction of new industries.

The area around the Dam crest has been landscaped and recreational installations are provided for the public.

Management of the catchment area is concentrated on the inner portion and maintenance of the forest areas is concerned mainly with the avoidance of forest fires and retaining the status quo with regard to tree growth.

At present access to the lake area is not available to the public.

Purpose and operation of the Dam concentrate on city water supply and some hydro-electric power generation.

No specific provision for flood mitigation was made in the design of the Dam.

Re-examination of environmental implications of the structure from time to time is considered desirable.

2. Locality Background.

The first white settlement in Australia was a penal colony of the British Empire established in 1788 on the east coast of the continent. This has grown to become the largest city in the southern hemisphere, the City of Greater Sydney, covering an administrative area of more than four thousand square kilometres with a population of about 2.9 million. Water is supplied for Sydney and the southern New South Wales coast by the Metropolitan Water, Sewerage and Drainage Board (M.W.S. & D.B.) who are also responsible for sewerage and drainage. The water distribution system extends over an area of more than two thousand square kilometres with over 16,250 kilometres of mains supplying a population of 3,065,000 persons (June 1977).

Ten storage reservoirs provide drinking water for this system. The most significant of them is Warragamba Dam and Lake Burragorang, the man-made lake created by it. (Map 1).

3. Warragamba Dam.

Warragamba Dam, seventy-five kilometres from Sydney, is a straight concrete gravity wall on sandstone foundations cut deeply into the floor and sides of the rock. The river carved a steep-sided gorge in the Triassic rocks. The magnitude of this large structure can be seen from the principal dimensions and data (Table 1) and the General Arrangement Drawing of the Dam. The period of construction extended over ten years with completion in 1960. (1)

4. Submergence of the Valley Upstream.

Before the Dam was built, Burragorang Valley, the valley upstream of the dam site, was extensively farmed for many decades with dairying, orchards and other crops. The towering rock cliffs gave the valley a natural charm enhancing a thriving tourist industry which flourished up to the last years before submergence.

When it became known that the construction of the Dam would cause flooding of the valley, the local inhabitants formed a Defence League in 1941 which asked for a Royal Commission on the need for Warragamba Dam. A Royal Commission was never granted. An area of 153 square kilometres, which included all properties to be submerged and those lying within three kilometres of the ultimate stored water, was acquired by the Board at the then current valuation price plus 10% displacement money. Land acquisition commenced as soon as construction of the Dam was approved in 1943.

5. Anthropological Aspects.

The Aboriginal population in the Burragorang Valley is considered to have been quite numerous before white settlement. However, apart from ethnological descriptions (2) and some records of the Aboriginal mythology relating to the topography of the area (3), few cultural records have remained. Before flooding there was an example of Aboriginal rock art in the Burragorang Valley which was well known as the "Hands on the Rock". This rock was submerged as the stored water rose behind the dam wall, causing the loss of this Aboriginal relic.

6. Construction Township.

A large work force for the construction of the Dam, which at its height exceeded two thousand persons, was recruited. To house these workers and their families, a township was established by the M.W.S. & D.B. on a mountain spur adjacent to the construction area.

At an early stage it was determined that the whole area to be submerged had to be cleared of standing trees. Up to 500 men were employed in the work of felling, cutting, stacking and burning the timber. Much of the local timber was used for Dam construction and fabrication of cottages.

With the completion of the Dam construction work terminated. Most of the engineers and staff were transferred to Sydney and construction workers were offered employment in the metropolitan area. As the township had temporarily lost its purpose, the resident population dropped to approximately one thousand persons.

Contrary to expectations and the usual pattern of construction villages, the population did not disappear. After a few years of stagnation, its proximity to the metropolis and its many facilities provided an opportunity for the establishment of decentralised industry which was subsidised by the State Government. Entertainment for visitors was catered for by an international company establishing a Lion Park. Currently the township is again flourishing with a population increased to 1700 persons and the younger age groups gaining prominence.

7. Recreational Use of the Area around the Dam Crest.

Following termination of construction work on the Dam, most of the works area was tranformed into a recreation area. Work sheds, equipment stores, workshops, barracks and major mechanical installations such as the aggregate rope ways, mixing plant etc. were disposed of. Roads were sealed and several large parking areas and parks extending to the crest of the Dam were established. Over two thousand trees and shrubs, mostly natives, were planted and a picnic area, about 1.6 kilometres long by 0.6 kilometres wide, with all facilities, was provided.

The public make extensive use of these facilities. Latest counts put the number of visitors to the area at approximately six hundred thousand per year. The installation of the Lion Park has provided an additional attraction as well as creating employment for the local population. This environmental anomaly, introduced in 1968, caters for an annual passage of approximately three hundred thousand persons through the five kilometres of roads within its boundaries.

8. Catchment Management.

The M.W.S. & D.B. manages the catchment area which, for convenience, has been divided into an inner and outer area. Practically no restrictions apply in the outer catchment, which includes several towns with a total population of sixty thousand. The inner catchment of 2 515 square kilometres, over which the Board exercises extensive power, includes all the lake area, the foreshores, a number of settlements, coal mines and many kilometres of public roads. Management of this vast area is devoted mainly to containment of existing hazards, control of pollution by coal mining activities and possible infringements of the Act. Tight controls are also enforced to prevent excessive urban development by subdivision within the small settlements. Farm management is subject to strict statutory regulations.

Within the whole of the catchment area of 9 013 square kilometres there is a great variety of topography and some variations in climate. More than half of it is relatively undisturbed, uncleared land, mostly timbered. This area is mainly in the centre of the catchment, while there are two distinct pastoral and agricultural areas in the north and in the south.

At this stage there is no intention to devote any part of the timbered area to silvicultural development beyond natural regrowth. Management is essentially "Protection Forestry", which basically means fire protection. To combat the threat of forest fires, some 560 kilometres of fire trails and fire roads, not accessible to the public, have been built and are patrolled by rangers. Two lookout towers have been constructed and radio connection is maintained with the adjoining Forestry Commission centres. Aeroplanes are used for fire spotting. Some of the worst fires are caused by lightning and it is not infrequent that several fires are started by a single thunderstorm, almost simultaneously.

The existing forest and vegetation cover is of vital importance in its effect on water yield, water quality and soil erosion. Research into the relationship of these factors and local conditions has been carried out by M.W.S. & D.B. and non-related organisations (4), (5), (6) and further investigations are in progress.

9. <u>The Lake Area.</u>

At present the public is not permitted within three kilometres of the water's edge of the huge Lake Burragorang created by Warragamba Dam except at the Dam wall and at Burragorang Lookout on the escarpment 600 m. above the lake level.

The recreational use of drinking water storage areas has been the subject of much discussion internationally and in Australia (7), (8), (9). In many locations recreational activities such as boating, sailing and fishing are acceptable and swimming is allowed in drinking water storage lakes, some of which are much smaller than Lake Burragorang. In these situations the water has to be adequately treated to achieve the quality required for human consumption.

Sanitary considerations are obviously of paramount importance. Contamination of the drinking water is known to give rise to mass infection where pathogenic organisms have been carried into the storage inadvertently (10).

At Warragamba the quality of the water reaching the outlets is high in accordance with international standards. The policy of excluding people from the lake and water's edge is strictly policed. With constant monitoring of water quality, only the provision of sterilisation by chlorine dosing is necessary.

10. Flood Protection.

The height of Warragamba Dam was determined by its purpose of providing a city water supply for Sydney. However, at an early stage of investigation it became obvious that the flow in the river is frequently in excess of supply requirements and what could be stored. A hydro-electric station of 50 000 kilowatts was incorporated in the Dam and has been producing power whenever stored water is available in excess of the "Safe Draft", providing an economic benefit.

The consideration of "Safe Draft" requires water to be held in the Dam to allow the maximum daily amount to be drawn continuously without fear of the storage being emptied. This must be designed for the duration of the "critical drought". In the case of Warragamba the most severe known drought, which extended over a period of eight years (1934-1942), is used. The effect of this drought is checked to ensure that with normal consumption the storage is not depleted to less than one year's supply. This criterion necessitates the lake being maintained constantly at the highest possible level.

As with any other river barrage the Lake acts as a buffer against floods, but flood mitigation was not a criterion for the M.W.S. & D.B. in the design of the Dam.

Some fifteen kilometres downstream of the Dam rich flood plains are used extensivly for fodder crops, animal husbandry, citrus growing and vegetable production. Warragamba Dam is provided with four radial gates 12.2 metres high and one drum gate 7.62 metres high to raise the storage level and facilitate flood discharge. It is not the practice of the M.W.S. & D.B. to pre-release water in anticipation of a flood.

Since completion of Warragamba Dam several floods have occurred, causing agricultural losses, hardship and discomfort to the residents in the valley downstream. The flood problem has been the subject of investigations since 1966. Several short term flood mitigation works were proposed, a number having by now been carried out. "Investigation into long-term flood-mitigation measures, including studies concerning existing and possible additional storages, are at present (1973) only in an early stage and no proposals have yet been developed". (11)

11. Summary and Conclusions.

Examination of the environmental implications concerning various aspects can be summarised as follows:

(a) Land Acquisition before Submergence.

The M.W.S. & D.B. as the construction authority showed considerable foresight in allowing more than ten years to elapse from the commencement of acquisitions to the time of submergence. By comparison Morgan (12) reports several incidents in U.S.A. at about the same time in which a construction authority gave the populations of the valleys to be submerged very little time for evacuation and no assistance to resettle.

(b) Aboriginal Relics:

It is regrettable that the "Hands on the Rock" was lost with the drowning of the Burragorang Valley. Consideration might have been given to its preservation by removing the whole of the rock with the painting to a position where it would not have been inundated. Growing awareness of the environmental significance of such Aboriginal art work should ensure its preservation in a similar situation today.

(c) Construction Township:

Warragamba township is an interesting example of social and environmental factors interacting to convert a construction village into a township with a new purpose.

(d) Forest Management:

Every effort must be made to prevent destruction of forest areas by bushfire. The existing stands of timber must be maintained and should be improved and extended where possible to provide better access for fire fighting and reduce erosion.

(e) Recreational Use-Water Quality:

Currently the Dam and Lake are used for city water supply and limited hydro-electric power generation only. Use of the Lake and catchment area for recreation would require new concepts of management and introduce completely new environmental impacts. Extensive water quality monitoring and chlorine dosing as currently practised must continue to be maintained to ensure continuation of the present high standard of water supplied. The recreational use of stored water and contiguous catchments areas is intimately associated with the ability to provide a water of acceptable quality for human consumption.

(f) Flood Mitigation:

A policy of permitting the lake water to be drawn down to a lower level would effectively reduce flood peaks, though not completely eliminating major floods. This would give some further protection to the activities of the population in the rich flood plains downstream of the Dam but would diminish the safe draft.

12. Examination of Desirable Studies.

In this analysis some of the environmental implications have been examined - with hindsight - which are considered significant at this stage after the Dam and the Lake have been in operation for over seventeen years.

None of the changes caused by the establishment of the Lake can be reversed. Minor changes are constantly taking place in and around the water body due to inflow and outflow conditions. Maintenance of the Lake to ensure its permanency, control of water quality and conditions of the catchment area as well as safety of the Dam structure and the population in the vicinity and downstream are environmentally meaningful.

Although this study does not claim to cover all the environmental aspects of this structure, it is an attempt to show that a review of major impacts is required during the life of the Dam and should be undertaken from time to time.

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HAWKESBURY – NEPEAN RIVER VALLEY

MILES 10 5 0 10 20 30 40 MILES

SCALE

H. BANDLER

MAP 1

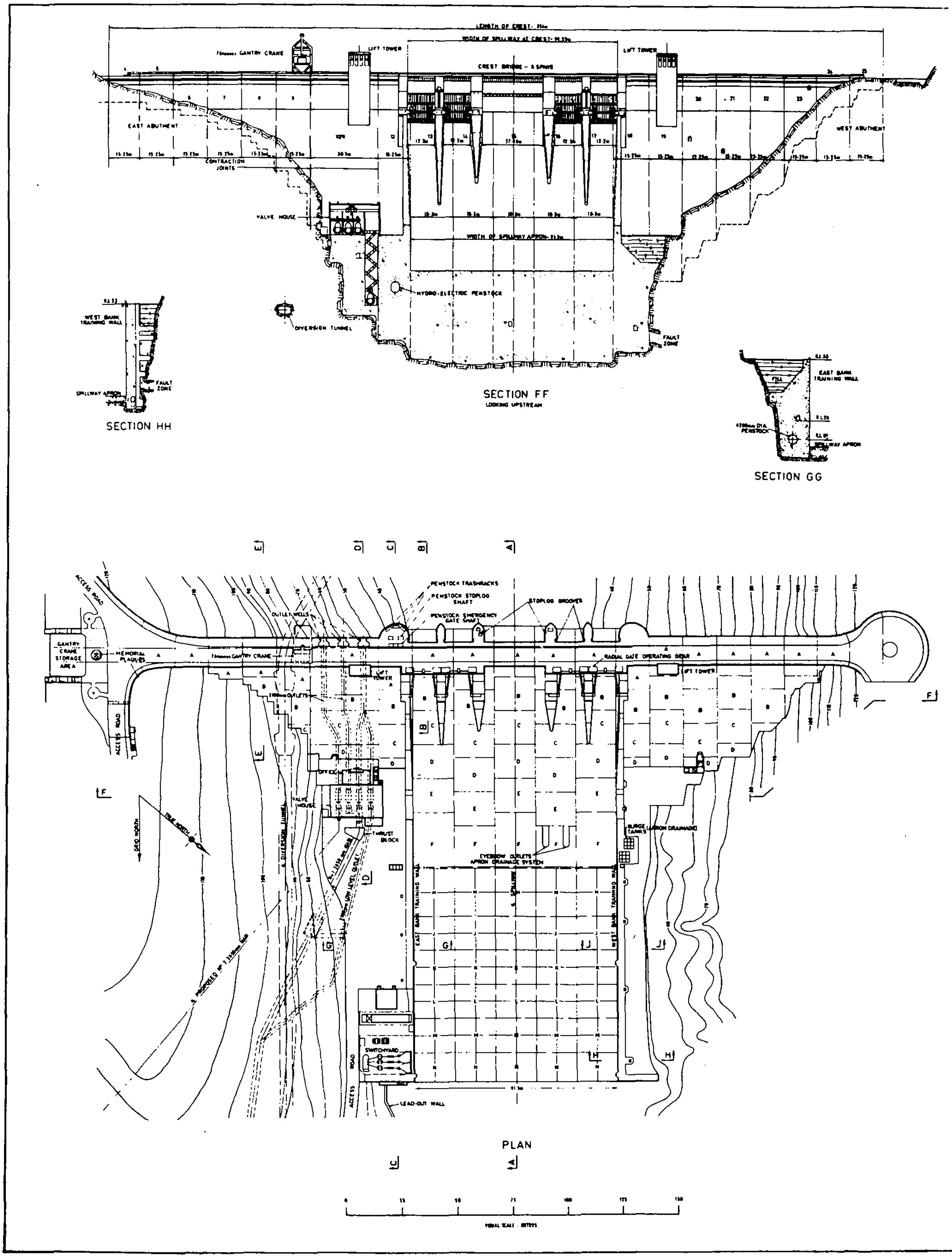
STORAGE CAPACITY	2,057,000 Mega litres
LENGTH OF WALL	350 m
LENGTH OF SPILLWAY OVER CREST	95 m
CONCRETE IN WALL	1.2 Million m^3
MAXIMUM HEIGHT OF CONCRETE	137 m
GREATEST DEPTH OF WATER	104 m
WIDTH OF WALL AT BASE	104 m
CATCHMENT AREA	9,013 km^2
ANNUAL AVERAGE RAINFALL	825 mm
ANNUAL AVERAGE EVAPORATION	1,270 mm
LAKE AREA AT FULL SUPPLY LEVEL	75 km^2
MAXIMUM LENGTH OF LAKE	52 km
LENGTH OF FORESHORES	353 km

H. BANDLER

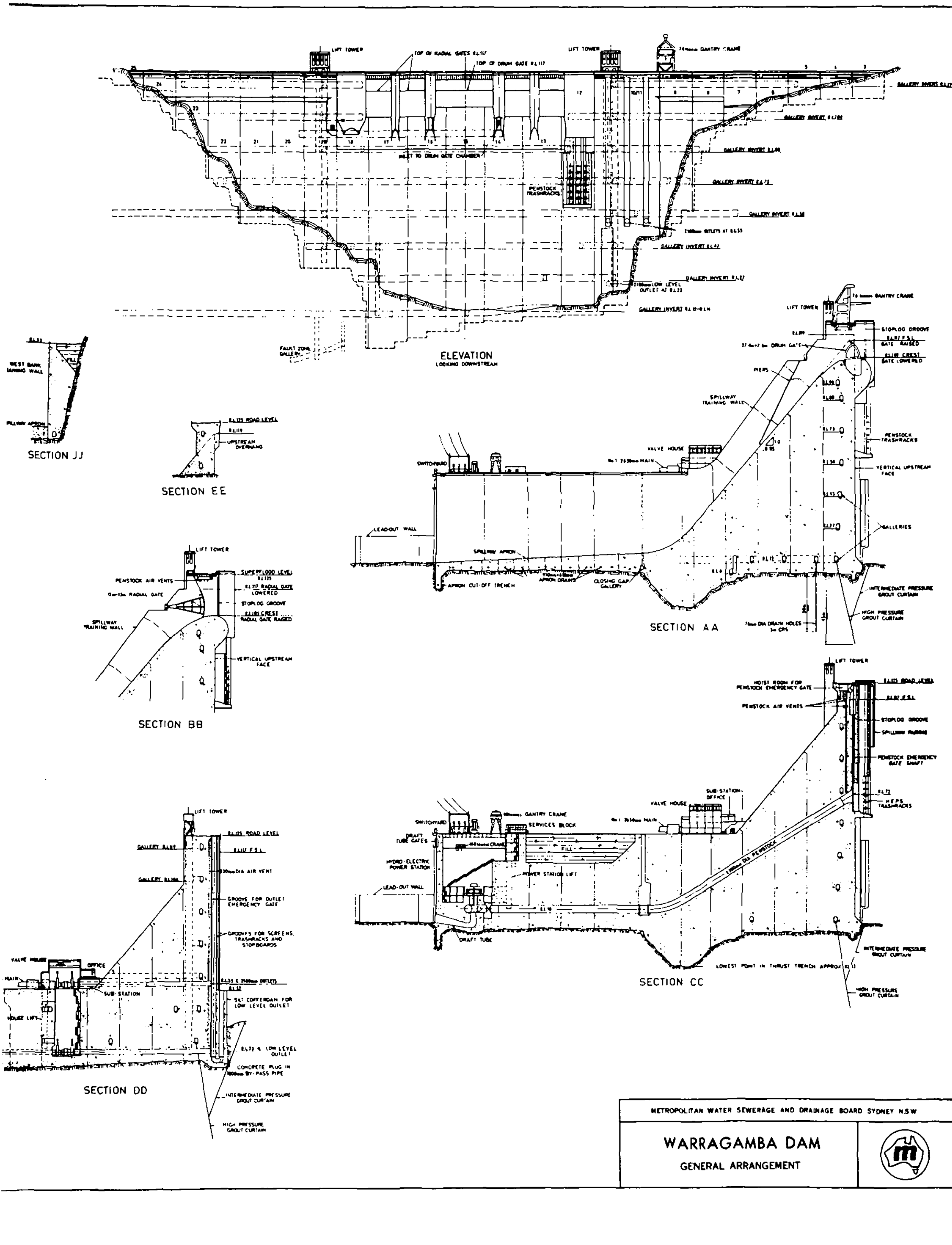
WARRAGAMBA DAM
PRINCIPLE DIMENSIONS AND DATA

TABLE 1

6a12



LENGTH OF CREST
WIDTH OF SPILLWAY AT CREST
GANTRY CRANE
LIFT TOWER
LIFT TOWER
CREST BRIDGE - 6 SPANS
EAST ABUTMENT
WEST ABUTMENT
CONTRACTION JOINTS
WIDTH OF SPILLWAY APRON
VALVE HOUSE
HYDRO-ELECTRIC PENSTOCK
DIVERSION TUNNEL
FAULT ZONE
WEST BANK TRAINING WALL
SPILLWAY APRON
FAULT ZONE
SECTION HH
SECTION FF
LOOKING UPSTREAM
EAST BANK TRAINING WALL
FILL
PENSTOCK
SPILLWAY APRON
SECTION GG
PENSTOCK TRASHRACKS
PENSTOCK STOPLOG SHAFT
PENSTOCK EMERGENCY GATE SHAFT
STOPLOG GROOVES
OUTLET WELLS
ACCESS ROAD
GANTRY CRANE STORAGE AREA
MEMORIAL PLAQUES
GANTRY CRANE
RADIAL GATE OPERATING GEAR
LIFT TOWER
LIFT TOWER
OUTLETS
ACCESS ROAD
VALVE HOUSE
THRUST BLOCK
DIVERSION TUNNEL
TRUE NORTH
GRID NORTH
SURGE TANKS
APRON DRAINAGE
EYEBROW OUTLETS
APRON DRAINAGE SYSTEM
EAST BANK TRAINING WALL
WEST BANK TRAINING WALL
LOW LEVEL OUTLET
SWITCHYARD
ACCESS ROAD
LEAD-OUT WALL
PLAN


LIFT TOWER
ELEVATION
LOOKING DOWNSTREAM
SECTION JJ
SECTION EE
SECTION AA
SECTION BB
SECTION CC
SECTION DD
METROPOLITAN WATER SEWERAGE AND DRAINAGE BOARD SYDNEY N.S.W.
WARRAGAMBA DAM
GENERAL ARRANGEMENT

Paper 6b

Present Status of Sea Water Desalination Technology by Reverse Osmosis Process in Japan

Yuichi Kunisada* and Yoshio Murayama**

Abstract

The development of sea water desalination technology by reverse osmosis [RO] process in Japan has made rapid progress in recent years, and modules with high rejection, high flux and high pressure resistance have been reached the stage of practical use. The Water Re-use Promotion Center [WRPC] has found that newly developed membranes should not need to be replaced for at least three [3] years by adequate pretreatment of raw sea water as the results of long-term continuous operation tests on these modules to assess membrane life. A demonstration unit with daily output of 500 m^3 fresh water is scheduled to be completed and put into operation in 1979. This unit will be equipped with Japanese-made modules and energy recovery system. Its operation is expected to demonstrate the economic efficiency and stability of the RO process.

Introduction

Compared to other sea water desalination technologies, the RO process has the advantages of the lowest energy consumption, simple and compact equipment and ease of maintenance and operation. In recent years, it has found a wide field of application.

RO plants with total capacity of over 70,000 m^3/day have been constructed in Japan. The majority is for desalination of low-salinity brackish water such as industrial, city or river water to produce boiler feed water or high-purity water. Apart from two or three small plants, there are as yet no plants for conversion of sea water to fresh water.

However, an absolute shortage of potable water is becoming a serious problem in Japan, especially in isolated islands and peninsulas. The sea water desalination is the fastest way of solving this problem, and several distillation plants on a scale of 1,000∿2,000 m^3/day have already been in use. But, with the four-fold rise in fuel prices since the oil crisis in 1973, the water cost of the distillation process, which uses large amount of fuel, has become extremely high.

In order to make the sea water desalination by the RO process to practical use, the WRPC has been carrying out since 1974 long-term continuous operation of several types of RO modules developed both in Japan and the U.S.A., under the sponsorship of the Ministry of International Trade and Industry. These tests have established the sea water desalination technology by the RO process and the prospects for its application.

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Japanese RO Membranes for Sea Water Desalination

Membranes for the sea water desalination are required to have, above all, i] high rejection and ii] high pressure resistance, which pose extremely difficult technical problems. Over the past few years, however, membrane development has been advanced at a rapid pace, making single-stage sea water desalination possible. Du Pont Co. has developed a follow fiber module named Permasep B-10, and U.O.P. has developed spiral wound modules [PA-300, etc.] of thin film composite membrane.

Membrane development has also made remarkable progress in Japan lately, leading to modules which are equal to those of American-made in terms of performance and durability.

Modified cellulose acetate [CA] is used in almost all cases as membrane materials. CA membranes, capable of single-stage sea water desalination, such as follow fiber membrane of Toyobo Co., have also been developed. Resistance to temperature, chlorine, etc. has also been greatly improved. One of new membrane material other than CA is the poly-heterocycles-poly-benzimidazolone [PBIL] developed by Teijin Co., which has excellent resistance to heat, chlorine and acidic condition of low pH.

The thin film composite membrane is now gaining worldwide attention as a substitute for the conventional CA membrane. The new type of membrane has a far higher permeat flux per unit area, giving it potentially high salt rejection and high temperature resistance. Membranes of this type are also being developed by Japanese manufacturers and will be used practically in the near future.

Besides the development and improvement of the membrane itself, enlargement of the module is also an important subject. By increasing the diameter of the module, the membrane cost per unit water quantity is reduced, together with construction costs and installation space, etc. Whereas the standard module diameter was four [4] inches until two or three years ago, modules with 8-inch diameter have now been developed in Japan as well as overseas. In the U.S.A., a 12-inch module for brackish water has already been developed.

Progress has also been made in the development of pressure vessels to house the membrane module. Such vessels must be able to withstand a high operating pressure of about 70 kg/cm^2 and the corrosive properties of sea water. Fiber-glass-reinforces plastic [FRP] has become to be used commonly at present.

The domestically manufactured RO modules installed in the Chigasaki Laboratory of WRPC are described below.

1] Spiral Wound Module

Toray Co. has developed a unique spiral module which differs structurally from the ordinary type. The feed water is introduced tangentially from the cylindrical surface and flows spirally along the membrane, as shown in Fig. 1.

Because of its unique structure, the module does not show telescopic deformation and provides very high recovery ratio due to minimized polarization on the membrane surface.

Table 1 gives the specifications of 4-inch and 8-inch modules for sea water desalination. A double-stage test unit having 16 4-inch modules [12 in the first stage and four [4] in the second] has been constructed at Chigasaki, and recorded about 10,000 hours of operation by March 1978. The product water permeated from the second stage maintained a value of 10 m^3/day and a quality of less than 300 ppm TDS.

This unit was then converted to consist of six [6] 8-inch modules [four [4] in the first stage and two [2] in the second] and has undergone approximately 5,000 hours of operation up to the present. Under conditions of a high recovery ratio of about 40% and a low operating pressure of 50 kg/cm^2 at the first stage, about 16 m^3/day of product water is obtained with a quality of less than 270 ppm TDS.

Fig. 1 : Configuration of Spiral Wound Module

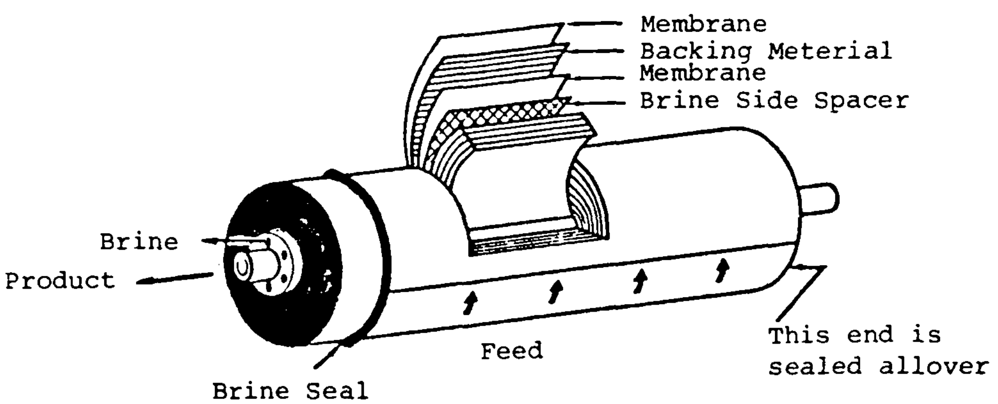


Table 1: The Specifications of Toray Spiral Wound Modules for Double Stage Sea Water Desalination

Module Type	4-inch	8-inch
Module Name	SC-5100	SC-5200
Salt Rejection [%]	94∿96	94∿96
Flux [m^3/day]	2.0∿2.4	8.0∿9.6
Element Size [mm]	∅102 x 1,016L	∅201 x 1,016L
Test Conditions		
NaCl Solution [ppm]	35,000	
Pressure [kg/cm^2]	56	
Temperature [°C]	25	
Recovery Ratio [%]	15	
Operating Conditions	Recommended	Allowable
Max Pressure [kg/cm^2]	56	70
Max Temperature [°C]	30	40
pH Range [ppm]	4.0∿7.5	3.0∿8.5
Max Chlorine [ppm]	1	3

2] Hollow Fiber Module

The follow fiber module, developed by Toyobo Co., employs a special cross-wrapped arrangement of hollow fiber, designed to minimize deposits of fouling materials on the membrane surface and to allow easy cleaning. The specifications of the sea water desalination modules are listed in Table 2.

Table 2: The Specifications of Toyobo Hollow Fiber Modules for Sea Water Desalination

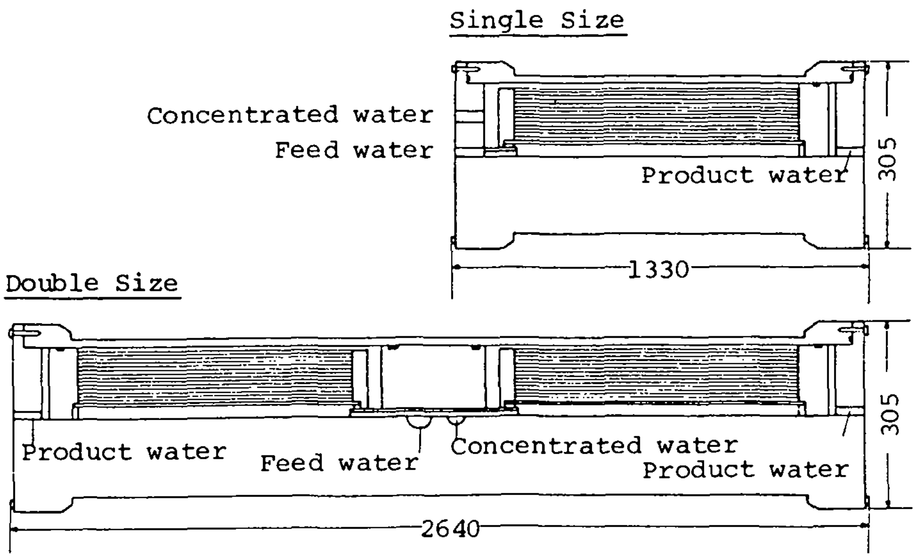
Module Type	5-inch Double Stage	8-inch Single Size for Single Stage	8-inch Double Size for Single Stage
Module Name	HR5350	HR8350	HR8650
Module Size [mm]	ø140 x 1,200L	ø305 x 1,330L	ø305 x 2,640L
Number of Element	1	1	1
Vessel Materials	SUS 316	FRP	FRP
Flux [m^3/day]	2.5	>10	>20
Salt Rejection [%]	94	>98.7	>98.7
Test Conditions			
NaCl Solution [ppm]		35,000	
Pressure [kg/cm^2]		55	
Temperature [°C]		25	
Recovery Ratio [%]		30	
Operating Conditions			
Max Pressure [kg/cm^2]		60	
Temperature Range [°C]		5∿40	
Suspended Solid [FI Value]		<4	
pH Range		3∿8	
cl_2 Tolerance		<1	

At Chigasaki, a double-stage test unit was first constructed with six [6] 5-inch modules [five [5] in the first stage and one [1] in the second], and was operated for about 6,000 hours until May 1978, with no replacement of the modules.

The membrance performance was then further improved and the module size was also enlarged. Tests are now being conducted on single-stage desalination using two [2] units, one for single-size module of eight [8] inches and the other for double-size module involving two [2] fiber bundles in series. The configuration is shown in Fig. 2.

The former has a productivity of 10 m^3/day and has been operated for about 5,000 hours, with a very little change in performance. The latter has been operated for about 2,000 hours under conditions of a high recovery ratio of 40% and an operating pressure of 55 kg/cm^2, yielding 20 m^3/day of product water with 200 ppm TDS.

Fig. 2: Configuration of Hollow Fiber Module



3] Tubular Module

Tubular-type modules in general are considered unsuitable for sea water desalination as they have small membrane area and low productivity per unit volume, and thus require high initial installation costs and a large site area.

However, their simple structure allows easy maintenance and does not require much attention to pretreatment of raw sea water since fouling does not readily occur. They may, therefore, be suitable as small-capacity plants for isolated islands and similar locations.

Table 3: The Specifications of Nitto Tubular Modules for Double Stage Sea Water Desalination

Module Type	NRO-A, B	NTR-U40
Module Size [mm]	ø190 x 2,674L	2,635L x 87W x 260H
Tube Number	18	40
Membrane Area [m^2]	1.75	3.88
Salt Rejection [%]	89	93.5
Flux [m^3/day]	0.30	0.50
Test Conditions		
NaCl Solution [ppm]	35,000	40,000
Pressure [kg/cm^2]	50	50
Temperature [°C]	25	25
Recovery Ratio [%]	-	7.5
Operating Conditions		
Max Pressure [kg/cm^2]	50	70
Temperature Range [°C]	5∿35	5∿35
pH Range	4∿7.5	4∿7.5
Cl_2 Tolerance [ppm]	1	1

Nitto Electric Co. has developed a tubular module for high-pressure use with an FRP support tube. The specifications of this module are shown in Table 3.

A double-stage desalination unit [1.5 m^3/day] with 16 4-inch modules [12 in the first stage and four [4] in the second] has been built at Chigasaki and has recorded about 6,000 hours of operation, being fed sea water pretreated only with a cartridge filter. Tests are presently being conducted to raise the module efficiency, using a unit-type module and high pressure of 65 kg/cm^2.

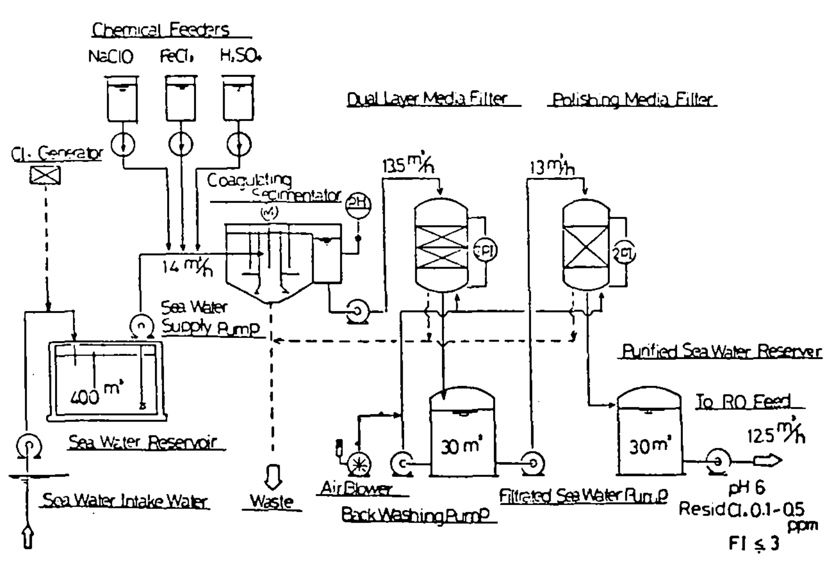
Pretreatment

A major problem in the RO process is the pretreatment of raw water. Removal of turbidity, microorganisms, hardness and colloidal particles from the sea water prolongs the RO membrane life.

A pretreatment system as shown in Fig. 3 has been build at Chigasaki, and sea water pretreated herein has been fed to the modules of both the hollow fiber and spiral types. The sea water pH is adjusted to about 6.0 by addition of acid, in order to prevent chemical decomposition of the CA membrane and precipitation of carbonates onto the membrane surface. Growth of microorganisms must be completely suppressed by addition of NaClO, and especially in the spring season higher chlorine concentration must be added.

Various methods of measuring the turbidity for the management of pretreated water quality have been proposed. Turbidity is usually measured by photometric or gravimetric methods, but these are not suitable in the case of low turbidity such as that of the RO pretreated water.

Fig. 3: Flow Diagram of Pretreatment System



Instead, factors known as the fouling index [FI], plugging factor [PF] and membrane filtration time [MF] are used. The module manufacturers specify feed water turbidity limits in terms of these indices. In the case of Du Pont's hollow fiber module, for example, pretreated water of FI 3 or below is required. At Chigasaki, a monitor has been developed to measure the FI value automatically.

The sea water used at Chigasaki is relatively clear, being drawn from an intake 600 meters offshore, and except during the spring season its values fall into the range of FI 5∿6, MF 180∿240 sec and turbidity 0.7∿1.0 ppm. The turbidity of this raw sea water is constantly lowered to FI of less than 3 by means of the pretreatment system which is consisted of a sedimentator, a double media filter and a polisher. Attempts are presently being made to simplify this pretreatment.

One approach is by the method known as direct [in-line] coagulation filtration, which eliminates the coagulation sedimentator. Although the frequency of back washing increases, the installation area and construction cost are cut down and unattended operation becomes possible. Nevertheless, to ensure that the FI of pretreated sea water remain less than 3 at all times, it is safer to pass the filtrate through a polisher once again, since two or three hours are required until the water quality stabilizes after back washing of the filter.

Another approach to simplifying pretreatment is the application of ultra-filtration [UF] process. Tests are now being conducted at Chigasaki on two types of hollow fiber modules developed by Asahi Chemical Co. and Kuraray Co. The former is a large module, eight [8] inches in diameter and two [2] meters in length, made of polyacryl nitrile fibers, and produces about 96 m^3 of permeate daily. The latter, made of polyvinyl alcohol fibers, has a 4-inch diameter and yields about 15 m^3/day of permeate.

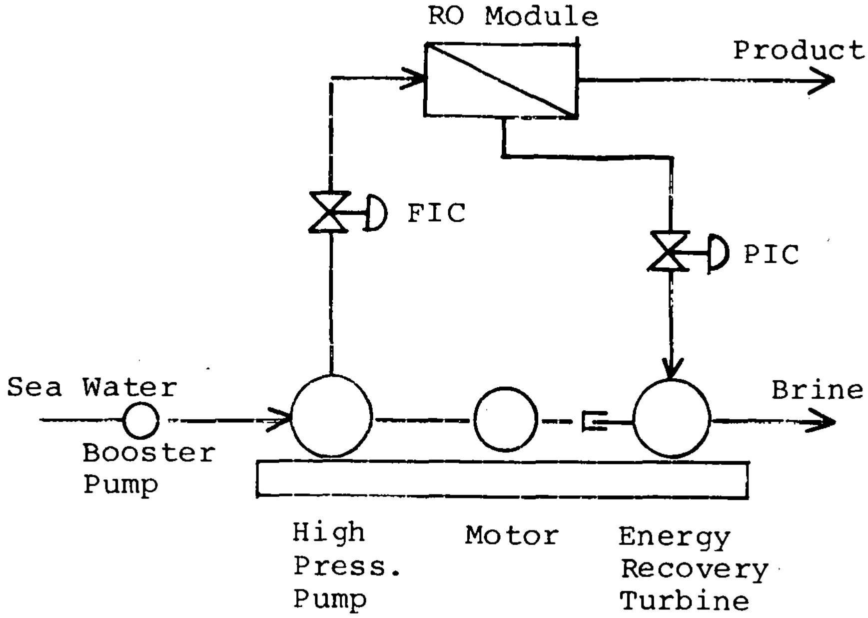
<u>Energy Recovery System</u>

The highly concentrated brine rejected from the RO module under high pressure can be utilized to recover energy. The methods usually adopted are either to use the brine to drive a turbine for power generation, or to use it as an auxiliary motive force for a high-pressure pump.

At Chigasaki, an energy recovery system comprising a high-pressure pump, a motor and a hydraulic turbine mounted on a co common base has already been constructed for incorporation in the 500 m^3/day unit that will be completed in the coming fiscal year. A flow diagram of this system is presented in Fig. 4.

Of the approximately 190 kWH required for the motor, about 45 kWH is supplied through energy recovery. The pump and turbine in the system have efficiencies of about 68% and 62% respectively, but if built on a larger scale they should be able to attain over 70% efficiency.

Fig. 4: Flow Diagram of Energy Recovery System



Energy Requirement and Water Cost

A major advantage of the sea water RO system is the low energy requirement as compared to distillation. The RO process requires 6∿8 kWH of electric power to produce one [1] cubic meter of fresh water, with accompanying fuel consumption of about one-third to one-fifth that of the distillation process.

Most of the power required by the RO process is to drive the high-pressure pump. This is determined by the operating pressure, water recovery ratio and pump efficiency. In the double-stage desalination process, there are additional power costs for the second stage, but these can probably be almost offset as it is possible to reduce the first-stage pressure and increase the water recovery ratio.

It is very difficult to present sea water desalination costs because they differ in accordance with conditions of plant site, costs for utilities and chemicals and many other factors. The fact that there are no large-scale RO plant in practical use is another reason for making the çost estimation difficult.

The greater part of desalination costs is consisted of power, costs for membrane replacement and depreciation, as well as expenses for labors, chemicals and maintenance. Costs for membrane replacement is estimated to be about one-third of the total costs on an assumption that life of membrane is three years. In the event when mass production of membrane begins to meet increased demands caused by succesive construction of large-scale RO plants, the above-mentioned unit cost would be reduced sharply.

It might be safe to consider that an RO plant of less then 10,000∿20,000 m^3/day capacity would be superior economically and technically compared with a MSF plant of the same scale.

Paper 6c

The Effects of Pollution on the Quality of Drinking Water

by Indonesian Water Supply Association

I. PREFACE.

From years to years there is a tendency of decreasing quality of raw water which is being used for filter plant I & II of Jakarta Water Supply where the raw water is coming from Flood Canal Water as the mixture of flow from Ciliwung river and West Tarum Canal which is coming from the Jatiluhur Dam.
On other side there is a need of stability of drinking water quality, which has to be accordingly with the Indonesian Drinking Water Standard; at the same time Jakarta Water Supply constantly utilities the original filter plants without any principal alteration; such kind of situation brings problems to Jakarta Water Supply to make the effort in serving good quality water to the consumers.

Some measures have been done in present time by using additional chemicals and maximalize the efficiency of the existing unit processes, but it's being expected possibilityof site effects among others the increasing of production cost; lowering the safety factors; and some by productpossibly being delevered to the users. Realizing the inter dependency one to the other, in facing the pollution to the raw water, the author always keeping opinion that to over-come the pollution, the best way is not using the technology as the first measure but preferably by regulations and Laws; because by technology means costy, beside the possibility of side reaction which might be some effect to the health of the people. In this case Jakarta City Administration did start considerably measures by issuing some decreas of Governor in regulating water stream in Jakarta there are

Decrea No. 484 dated June 30, 1977
On : Creteria of surface water based to the usage in Jakarta City Administration;

Decrea No. 382 dated June 9, 1977
On : The obligation to the industries and other services to send the waste water to the environt-mental laboratory (PPMPL) Jakarta and others nominated laboratories.

Even-though the realisation has to be well enforced,but by the present of the said decreas, at least as a kind of guidline to the services who are is charge to the usage of water stream in Jakarta.

On the same time Jakarta City Administration aware that bigger portion of pollution are coming from domestic waste, this is the reason for the controlling services have to work hard in realising the above mentioned decreas.

In fact Jakarta Water Supply at present just serves arround 45% of populations, in this case the scope of this paper only li - mited to the said percentage, and beyond that figure most of the people solve the water problem by their own, and almost sure part of them have had experiences on pollution stage, which is effecting the water being utilized by them, but their problem hav'nt yet being monitored by coordinating body which might distinguish and solve the problem intensively; some time the problem directly being exposed by mass media, hoping by this way the may warn to the services in charge, and solve the pro - blem promptly. This kind of solving the problem surely not the correct one, because the common people who are'nt get use to the pollution problem easily let the things go to certain extent (mostly up to a serious stage of pollution). This will cause some difficulties to solve and usually more costly and possibly might bring hazard to the people's Health.

6c4 II. SORTS OF POLLUTION IN RAW WATER JAKARTA.

Sorts of pollution presently hapens in the raw water for Filter Plants in Jakarta might be classified in 3 (three) major group :

a). Coming from Industries, among others :
- In-organic substances and heavy metals;
- Color;
- Organic substances.

b). Coming from domestic :
- Solid refuses;
- Human Wastes;
- Detergent.

c). Coming from oxidation ponds in polder area consist of Septic Water.

Explanation :

a). Wastes which are coming from Industries.

- In organic substances and heavy metals.

Eventhought at present in Jakarta City Administration having fixed location for Industries namely Pulo Gadung area (Jakarta Industrial Estate), but still quite amount of Industries are built out side of Pulo Gadung area (especially Industries which were built before the present of Jakarta Industrial Estate), the licences of the said Industries durable to several years before moving to the relocation area, and also several Industries which are located out side of Jakarta City Administration but the wastes are thrown in Ciliwung river and the up stream creek of Ciliwung river, by this activities, Ciliwung river are being loaded by the waste and such kind of water is being used by Filter Plants of Jakarta Water Supply.

Sorts of Pollution from Industries are being monitored easily since the special character among other in organic content, e.g. phosphates, sulphates, chlorides, Barium, pH, hardness and heavy metals such as Mercury, Copper and Chromium, though in normal season the contents are quite safe as rw water, but frequently happen the consentration big enough during dry season, where the dilution from West Tarum Canal becomes less and amount of pollutants are constant. Efforts have been taken by Jakarta Water Supply by trying some neutralization process and intensifying the flocculation process, by this way parts of the inpurities might be decrease in concentration and settling down at the same time with flocs which are formed,

and the water produce at the end of the process still in accor - dance with drinking water standard; especially the Barium content and heavy metals the effort are not only up to the process but also trying to find the sources of pollution, because the target is enforcing the obligation to the industry concerned has to treat the waste as such to eliminate all the dangerous substance to a certain level.
In the mean time the effort some time found difficulties especi- ally when the industries are home industries scatering around Jakarta, they are not easy being identified.

- Color Substance.

It's fully undoubt that along Flood Canal and Ciliwung river, there are industries which are desposing wastes consist of color substance with complex chemical composition; It was easily emagine the difficulties to process in reducing the intensity of the color, since decolorizing process used to be classified as highly costed process; And the difficulties becoming more serious when desposing color substance being done in a sudden and completely irregular and completely unmastered when it happens at night.

Efforts have been taken by Jakarta Water Supply by using acti- vated Carbon, to adsorb the color and being settled at the same time with flocculation and coagulation process. In the dry season the intensity of color quite high and needs the feeding of acti- vated carbon as such causes increasing the production cost by Rp. 5,-- to Rp. 10,-- for every Cu M water produced. (US.$.1,--= Rp. 415,--).

- Organic Substances :

Organic substances with the various concentration from time to time in the raw water especially which are coming from industrial waste and domestic waste, and extremely increase during dry season. The over come this problem by applying oxydising process by using Calcium hypochlorite or chlorine gas as oxydants; butunfortunately as the side reaction producing chloromethan - chloropenol which are causing an extremely strong unpleasant odor, that is why apply- ing chlorine as oxidant some times in combination with activated carbon to deodorize and this also causing another increasing pro- duction cost by Rp. 7,-- / Rp. 11,-- per Cu M water produced (US.$.1,-- = Rp. 415,--).

b. Domestic Waste.

- Solid refuses.

  In fact the desposing solid refuses are not necessarily happen when people are realizing the decreas which are presently exist, and people like to obey with highly discipline, that solid refuses are desposing on the land and not to the water stream, especially when the use of it, is as raw water for drinking water. But what ever it should be, the reality is that solid refuses are present in considerable amount and this is the fact, in this case the efforts of Jakarta Water Supply is using multy stages type screens, by this arrangement may reduce bigger parts of solid refuses in the raw water, but frequently facing difficulties when the solid refuses consist mostly plastic sheet this may "penetrate" through screens and causing difficulties for pumps and other unit processes.

- Faecal Waste.

  The raw water of Jakarta Water Supply in present time suffering from the faecal waste directly desposted from the houses; this phenomena easily be distinguish visuelly, by bacterial count or further examination of E. Coli per unit volume of raw water and also the ammonium content in raw water.
  If we try to compare the standard creteria of raw water has to be;so the reality in present raw water is for deviated to the high side.
  For that reason during the awaiting period for the permanent solution to the faecal waste from the services concern to the water stream, the efforts of Jakarta Water Supply is applying pre chlorination as such so that the raw water always has a residual chlorine to eliminate the negative effects of the faecal waste, of course the use of extra amount of chemical always increasing the production cost and also some side reaction as by products.

- Detergent.

  The more widely use of synthetic detergent brings some effects on the detergents content in the raw water for drinking water and especially in the dry season, where the dilution effect from West Tarum Canal becoming less. The negative effect of the present detergent content in the raw water mainly on the estetic point of view.

Jakarta City Administration with the decrea No.391 dated June 14, 1977 and being reviewed in the decrea No.705 dated October 12, 1977 about restriction of marketing and producing " hard " type, detergent hoping this may solve part of problem in the raw water for drinking water.

C. Pollution coming from small dams.

Setia Budi dam and Melati dam, recently used for flood control but it's also being used as collecting basin for domestic waste, some time the kind of water in these dams the same as septic water and this kind of water being discharged to Flood Canal, and the use of water is for the raw water of drinking water; Seems this is very unusual condition but it is the fact. And now the step is how to solve the problem at present and also for the future. There are 2 (two) kinds of efforts have been implemented, it is by reducing debiet of discharge during the pumping from the both dams, so that it's time enough for dilution from the water stream it self, and the other effort is by passing canal so the location of discharge is at the down stream of water Intake point of filter Plant I & II.

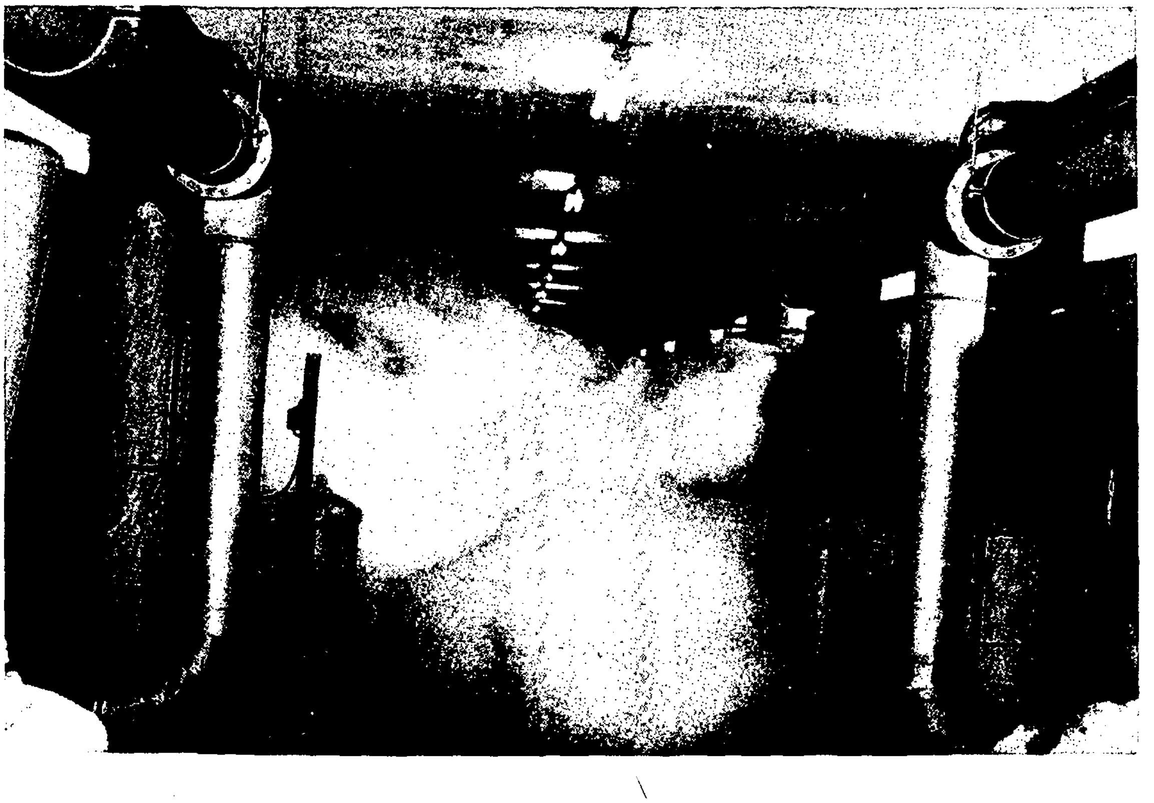
The way of monitoring the effect of water from the dams is by determining the D.O. (desolved oxygen) content from time to time every day to get the correlation between decreasing of D.O. in the discharging period of the dams' water.

III. THE EFFECT OF POLLUTION AND PROBLEM SOLVING.

The effect of pollution it is clear causing the big deviation between the present condition of raw water compairing with the creteria of the raw water which are specified in the present decree; the present situation has to be solved promptly and being realised that there it'nt good point by letting the problem undisolved; because even though there are some efforts of Jakarta Water Supply to fight the problem but these efforts are curing in charactor causes increasing of cost of production beside decreasing the safety factor.

The best solution is of course prevention and to keep the water stream as it is specified for the kind of usage.
During awaiting period for permanent solution in Raw Water, Jakarta Water Supply is taking emergency measures which are mentioned on Chapter II, while the long term solution is laying the raw water pipes as such so that later the raw water is free from pollution along the route.
Beside the above solution it was thought the possibility of having raw water reservoir as buffer stock to stabilise the quality of raw water against the sudden change of raw water which is frequently occur.

In addition of all the above solution the important one is reaching the succesful enforcement and implementation the present decrees.



IV. CONCLUSION.

The effect of pollution against the quality of water produced, the sure thing is increasing the production cost and decreasing the safety factor; in the mean time the quality water produced keep it constant as it is specified in Drinking Water Standard.

The above mentioned problem could'nt be letting forever; solving the problem the sooner the better; several sugestions are as follow :

1). The need of non regional decree, because the pollution always has correlation with other region.

2). The need of executing body to enforce the decree.

3). To find the financing to over come the domestic waste and industrial waste.

4). For big cities in Indonesia the seasonal effect of pollution on raw water has to be solved with a kind of emergency solution.

V. ATTACHMENTS.

1). Decree of Governor No. 382 year 1977 dated June 9, 1977 about : The obligation of Industries and other Services in Jakarta City Administration to analyse the waste water to the Environtmental Laboratory (PPMPL) of Jakarta City Administration or other nominated Laboratory.

2). Decree of Governor No. 484 year 1977 dated June 30, 1977 about : The creteria of quality of Water in the Water stream based to the usage.

3). Decree of Governor No. 391 year 1977 dated June 14, 1977 about : The restriction marketing and producing Hard alkylate and replaced by Soft alkylate.

4). Decree of Governor No. 705 year 1977 dated October 12, 1977 about : Review on Decree of Governor of Jakarta City Administration No. 391 year 1977 dated June 14, 1977.

Paper 6d

Fresh Water Problems in the Netherlands and their Solutions

By ESMIL International B.V. (Holland)

SUMMARY.

The Netherlands are one of the countries in the world most abounding in water. About one-fifth of the total area of 38,000 square kilometres consists of water originating from precipitation. For technicians responsible for the water supply in arid territories it must be incredible to hear that nevertheless there are big problems with the fresh water supply in a country like the Netherlands.

The Western part of the Netherlands and especially the coastal region along the North Sea in which the biggest cities of the country, Rotterdam, Amsterdam and The Hague are situated, is by far the most industrialised part of it. This territory also having the greatest density of population it is evident that the demand for water for industrial as well as domestic purposes is highest there.

Until about 1955 the Northern part of this region in which Amsterdam and The Hague are located could draw its fresh water from the subsoil reservoirs found in the coastal dunes. Due to the post-war rapid expansion of industrial development this resource cannot meet the requirements any longer. It is for that reason that the high quality water from the Dunes is being made up by infiltrating River Rhine water into the coastal Dunes. This river has a basin of about 16,000 square kilometres in which vast industrial areas in Germany, France and Switzerland are situated with a population of approximately 40 million people. As up till now most of the industrial and domestic waste water is dumped into the river without any treatment it will be clear that by the time the water crosses the Dutch border it is heavily polluted with matter of organic as well as inorganic origin. The concentration of this matter is closely related to the fluctuating drainage of the river. In order to make this water suitable for consumption it is at present chemically treated by the Dutch Waterworks so that the major part of the organic matter is removed. However, the inorganic matter, so the salt content of the water, is practically not affected by this chemical treatment.

In comparison with the other constituents of inorganic origin the chloride content of the River Rhine water is very high. To a great extent this is due to dumping of waste salts into the river by the potassium mines in Alsace (France). Consequently the river water has a chloride content that, at low river, can be as high as 350 mg/l. Bearing in mind that the water supply authorities in the Netherlands are aiming at the delivery of water with a maximum chloride content of 150 mg/l. Preferably 100 mg/l., and that the salt content of the River Rhine will most unlikely decrease in the near future it is obvious that even in watery Holland it will be inevitable to desalinate in order to supply good quality water for domestic as well as for industrial and

agricultural purposes.

At present three multi-stage flash type evaporator plants are operating in the Netherlands with a total capacity of about 80,000 cubic metres per day (more than 21 mgpd), over 100 small reverse osmosis units, ranging from 5 to 100 cubic metres per day, with a total capacity of about 4,000 cubic metres per day (about 1,000,000 gpd), and one reverse osmosis unit with a capacity of 1000 cubic metres per day (about 250,000 gpd).